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Scientists researching teaching : reforming science education & transforming practice.

Tarin Harrar Weiss
University of Massachusetts Amherst

SCIENTISTS RESEARCHING TEACHING: REFORMING SCIENCE EDUCATION & TRANSFORMING PRACTICE

A Dissertation Presented

by

TARIN HARRAR WEISS

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Approved as to style and content by:

Allan Feldman, Chair

Kathleen S. Davis, Member

Richard F. Yuretich, Member

Andrew Effrat, Dean
School of Education

DEDICATION

To my parents, Sallie and William Harrar and to Tad, Hannah, and Ida

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I come to this place because of my parents, who always instilled in us a love of learning and a respect for education. My siblings, Sarí, Ardis, and Bill always set a high standard for me to follow.

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ABSTRACT

SCIENTISTS RESEARCHING TEACHING:

REFORMING SCIENCE EDUCATION & TRANSFORMING PRACTICE

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TARIN HARRAR WEISS, B.S., UNIVERSITY OF MASSACHUSETTS AMHERST

M.S., UNIVERSITY OF WISCONSIN MADISON

Ed. D., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Allan Feldman

Reforming science education is a multidimensional and complex undertaking. Of extreme importance is transforming how teachers teach. Answering the equity call of reform initiatives requires focusing on the underlying values and beliefs guiding teacher action and the promotion of inclusive practices (Brickhouse, 2001; Harding, 1994; Eisenhart, Finkel, & Marion, 1995; Mayberry & Rees, 1999; Rodriguez, 1997). Reform efforts within the last decade are being directed at college level science courses. Course and pedagogical transformations are particularly aimed at increasing the numbers of females and persons of color in science and improving the education of preservice teachers. Facilitating transformations toward these goals at the individual and program level is challenging work.

This study explores and describes the conditions of the teacher change process toward an inclusive pedagogy. Two science professors affiliated with a reform collaborative were the main participants of the research. The professors, in collaboration with the primary researcher, engaged in assisted action research that lead to the identification and descriptions of their context and practical teaching theories. Among the questions explored were: "How does placing the professor in a position to conduct an assisted action research project help to foster teacher change conditions?" "How do the practical theories guiding the professors' teaching foster or impede inclusionary practice?" "What necessary conditions of the teacher change process toward an inclusive pedagogy emerged from the study?"

Using case study and ethnographic qualitative research strategies for data collection and analysis, this study affords a unique perspective through which to consider why and how science professors change their practice. Data indicated that the assisted action research strategy fostered the conditions of teacher change. In addition, findings revealed that the professors shared a teacher and curriculum centered teaching philosophy and an ethic of care and respect for their students that, in varying ways, both supported and impeded inclusive practice. Teacher change was heavily mediated by departmental contexts. Assertions are made about the necessary conditions of teacher change toward an inclusive pedagogy and implications for further research are explored.

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CHAPTER 1

INTRODUCTION

Science for all.

I think that notion, now slogan, gave feminists anxious hope when it received national attention over a decade ago. Yet today, feminists publish a "Call to Action", in order to "forge a community of science education activists" who will "explicitly challenge the status quo" of science and science education (Cavazos, Hazelwood, Howes, Kurth, Lane, Markham, Richmond, & Roth, 1998, p. 343). Why?

Nina, an English major, quoted from a study I conducted in an introductory level biology course helps to frame the issue:

> I hate science, I still hate science, I can't stand it, I just don't get it. I like words, I like the way they're put together, I like the structures. I like all the technical sides of it and all of the creative sides of it. But I just don't deal well with numbers at all. So every time science is introduced to me I think numbers and I think, "Oh God, not again." And so I just try to avoid it at all costs.
>
> I did take a physical science course, I took astronomy... [the professor] was really nice. And I thought that information was the most interesting information I could have ever learned. I got a D in the class though. It doesn't function in my head. I sat there and I read the text and I looked up all this extra information and I thought it was just the greatest thing and maybe I'll become an astronomer... but I just didn't get it. I thought it was interesting. I could read about the planets, I could read about what their temperatures are like and all that, but when it came to the physics of it all, totally went over my head. I did not get it no matter how much I tried.
>
> [The teaching] was so boring. He just lectured and lectured and lectured. Literally more than half of the class was asleep by the time it was time to get out. Attending the lectures were not mandatory so I stopped attending lectures and read on my own, and I learned so much more during the second half of the year than I did the first half. It was better when I read it than we he lectured it to me.
>
> Smaller classrooms tend to be better because you don't have to strain to hear the teacher, you see what's going on instead of just kind of watching away. I had a [high school] chemistry class, the teacher's name was Fitz. Our class was really small and he used to just blow things up for fun and we'd be so close, and he wouldn't let us know it was going to blow up until he ran to the back of the room. By that time, stuff was all over the ceiling and all over the sides. He had pictures but he had them in glass so that way he could just wipe them off when he was done. And there weren't the typical lab tables, they were circle tables were a bunch of students sat in a half circle. There were 3 of them.
>
> ...if he wanted to seem less intrusive, he would sit with us and then he'd send a student up front while he ran the class seated. It [was] a small classroom.

> And just the way the room was set up made you pay attention, you couldn't sit in a spot where he couldn't see you. You were always facing him and he's always looking at you and it made you pay attention. The stuff all over the ceiling always made you wonder what he was going to do today. And he'd explain what he was going to do or he'd wait until he'd do it and then he'd explain what happened. I don't know, I liked the messiness on the sides, the pictures, and the glass. The best thing was not the long black lab tables and not desks like these there was working space but you were also ... with other students. [You] weren't seated by yourself in a row, you were in a friendlier position.

A "friendlier position" versus not getting it "no matter how hard I tried"... Nina sums up the disconnect she has felt in science classes so well. Science is interesting, but she can't get it - can't do it. And, though she expresses frustration, there is no anger or expectation that things should be better. Instead she pays thousands of dollars to attend college and is driven to skipping classes to learn the course material on her own. "I learned so much more during the second half of the year than I did the first half", she said, yet, who knew what she learned? A faceless student I.D. number, her efforts earned her a D.

Nina's reflections are cause to be incensed! Is she part of the "science for all" rhetoric? At times I believe she felt that science was for her, but more often she felt that it was not. What is her message to the science education community? She offers us an important key to her experience; the teacher. We see in her descriptions how teachers were pivotal to her sense of membership or belonging in science. Acting on such realizations prompted the study described in this paper. It is a study about teacher change and how science professors make sense of reflections from students like Nina. It is a study of scientists as teachers and the impediments to their enactment of an explicitly inclusive pedagogy.

This study explored and described the factors contributing to and impeding practical implementation of the "science for all" notion. My work employed the methods of critical qualitative research (Rossman & Rallis, 1998; Miles & Huberman, 1994; Lincoln & Guba, 1985) and interacted with participants and data from a feminist perspective paying close attention to issues of authority, position, empowerment, voice, and cultural bias (Middlecamp & Subramanium, 2001).

The mechanism used to initiate teacher change was an assisted action research project (Elliott, 1991; Feldman, 1998, Stenhouse, 1975). Incorporated into the project were sustained collaborative conversations (Feldman, 1998) between the professors and the researcher (me) in the roles of critical friend and facilitator. Data sources guiding our conversations were professor/ student interviews, classroom observations, student response sheets, and document analysis. As it endeavored to involve the personal and practical concerns of professors and students in the teacher change process, the study is a critical contribution to the science education reform literature base.

The Problem

Background of the Problem

Historically and presently, science education is not achieving scientific literacy for the majority of our citizens. Miller (1991) suggests that as much as 90% of our populace is scientifically illiterate. In an age of information and technology, where the average worker needs more education and training (Toffler, 1991), this is a disturbing statistic.

Feminist and historical perspectives offer us insight into this phenomenon. In general, the explanations assert that this scientific elite is the expected product of K-16 science education, the scientific community of practice, and society's cultural norms. The structure and culture of our society offers those in the dominant culture pathways to legitimate participation in the scientific community of practice while keeping females and people of color on its periphery (Davis, 2001; Lave & Wenger, 1991). The study in this paper explores how this phenomenon plays out on the stage of higher education and how teacher change is integral to its disruption.

Numerous studies have concluded that there is a need to reform undergraduate science education (Astin & Astin, 1993; Gess-Newsome, Southerland, Johnston, & Newberry, 2001; NSF, 1996, 2000; Seymour & Hewitt, 1994; Seymour, 1995; Thom, 1998;Tobias, 1990, 1992). The political call to revise undergraduate science, math, engineering, and technology (SMET) education was begun in 1993 when CUSE Committee on Undergraduate Science Education was developed by the National Science Foundation's (NSF). For five years the committee held symposiums with hundreds of SMET faculty, administrators, and integral others to create a plan of action for the revision of undergraduate SMET education. Around the same time the National Research Council focused on the necessary link between the Standards and higher education.

Since that time, many publications have elucidated the recommendations of various prestigious committees: the NRC's From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology (1996); the NSF Advisory Committee's report Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology (1996); the Boyer's Commission report Reinventing Undergraduate Education: A Blueprint for America's Research Universities (1998); Institute for Research on Higher Education's paper "A Teachable Moment" (1998) and College Pathways to the Science Education Standards (NSTA, 2001). What these publications share is a fundamental goal of science for all. In general this requires that all undergraduates take SMET courses and learn through engaging and challenging coursework. Focus has been on linking student learning in SMET with K12 educational experiences, continuance of the Standards into higher education, interdisciplinary and inquiry based teaching, connections of science and society, continual evaluation of college programs, responsibility for the education of future teachers, promoting effective teaching through recognition and rewards, motivating graduate students to become k12 teachers, providing opportunities for current faculty to become better teachers. This focus is summed up in the latest NRC publication, Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology (1999). Funding agencies, such as NSF, the Howard Hughes Medical Institute, the Pew Charitable Trusts, and the Exxon Education Foundation are supporting reform efforts in higher education.

Of those majoring in SMET, 47% are female (NSF, 2000a). Ethnically, there is much variation within that percentage as Asian women are over-represented, white women are underrepresented, and African American, Hispanic, and Native American women are severely underrepresented. Female participation in SMET has increased over time, with certain fields (biological disciplines) being more popular for females than others. As a group, women achieve the highest representation in the biological sciences at 50-56% (NSF, 2000a; NSF, 2000b). However, stagnant or downward trends still exist. Female enrollment has declined in computer science, from 37% in 1984 to less than 20% in 1999 (Thom, 1998) and remains low (18%) in both engineering and physics (NSF, 2000a). In addition, the higher percentage of those who switch out of SMET majors (85% in engineering, 51% for each biology, physics, chemistry, and 63% in math) are female (NSF, 2000a; Seymour, 1995). Hierarchical segregation (Schiebinger, 1999) illustrates the multiple stages of decline that occur as women move into SMET graduate degrees. For example, women earn 54% of bachelors degrees (50% of those in science) yet only 40% of the doctoral degrees (31% of those science and engineering).

As expected, fewer females than males are represented in the science, engineering, and technology (SET) labor force. At the career level we also see disparities in female representation, salary, and job type. Women make up 46% of the labor force and only 19% of the SET workforce (of which 82% is made up of white males) (NSF, 2000a). Again, females congregate in the life sciences, making up 36% of that professional field while only holding 23%, 22%, and 9% of jobs in physical science, computer science, and engineering, respectively (NSF, 2000a). Inequities also exist between median salaries for women and men in science, engineering, and technology. Females get paid, on average, 15-17% less than their male counterparts even when the statistics are corrected for age, experience, and education - and the gap widens with age (except for engineers in industry) (Schiebinger, 1999; NSF, 2000b). With respect to job type, although three-quarters of all SET jobs are in industry, more men than women have the benefits of these well-paid salaries (NSF, 2000a).

Instead, women in SET jobs are over-represented in government and educational institutions (NSF, 2000b). In academia, women are more present in the "soft sciences" (the life and behavioral science departments) where salaries are generally low regardless of sex. Additionally, women make up only 11% of full professorships (even though they have earned more than 25% of the doctorates since 1970) (Thom, 1998) and less than 1% of deans (Shiebinger, 1999). Finally, even once they are in SET jobs, women are twice as likely as men to leave their positions and those in industry leave in double the numbers than those in public and non-profit fields (CWSE, 1994).

Schiebinger (1999), summarizing the work of others, explains that "it takes 400 ninth-grade boys to get one Ph.D. scientist but 2,000 ninth-grade girls" (p. 55). Of course, participating in science does not require being awarded a Ph.D. in a scientific discipline but these numbers are compelling. Participating in science can mean working in a scientific field as well as using scientific knowledge and thinking in one's job and everyday life. This requires maintaining female's interest in science. How many of those 2,000 girls will determine that science is relevant to their jobs and personal lives? Scores of females are lost out of the science "pipeline". How do we keep them? Seymour & Hewitt (1994) contend that

> From our data...the most effective way to improve retention among women and students of color, and to build their numbers over the longer-term is to improve the quality of the learning experience for all students--including those non-science majors who wish to study science and mathematics as part of their overall education.

A highly publicized goal of science education reform is to improve the quality of the learning experience for all students, especially that of females and minorities. Many efforts have been launched since the 1970s to ameliorate noted dissimilarities in test scores, course taking, interest, and college majors. For example, following the rise of the second wave of feminism (Weigand, 2001) and the ensuing "women's liberation movement", the federal government was pushed to ensure, at least structurally, that females would have the same educational opportunities as males.

Sadker & Sadker (1994), in their significant book Failing at Fairness, How Our Schools Cheat Girls, effectively sum up the federal initiatives. In 1972, Congress passed Title IX. The passage of this law, impacting all levels of schooling, required equity in school athletics, career counseling, medical services, financial aid, admissions, teaching practices, the treatment of students and the hiring/promotion of teachers. Two years later, the Women's Educational Equity Act (WEEA) passed. This act, with an initial budget of 10 million dollars, offered funding for research, training, and materials aimed at eradicating gender inequalities. "WEAA projects ranged from creating strategies to helping schools comply with Title IX to recruiting girls into math and science" (pg. 36). Additionally, in 1978, the Civil Rights Act was expanded by creating "sex desegregation assistance centers... to assist teachers, parents, and students in developing nonsexist programs" (pg. 36). However, these efforts were never fully realized.

> As the 1970s drew to a close, disappointments mounted. It became clear that the hope placed by educators in the power of Title IX was not to be fulfilled. The law may have been on the books, but many schools did not take it seriously. In one school only boys were allowed to take advanced math courses. In another, vocational programs remained

segregated with cosmetology and secretarial courses only for women and electrical and automotive courses only for men. In another community, pregnancy was grounds for expelling teenage mothers, but teenage fathers were not expelled. Many school districts spent twenty times as much on boys' sports as girls' sports. One college awarded ten times as many scholarships to males as to equally qualified females. Complaints were lodged, paperwork piled up, delays were common, and penalties became a new mythology, for they were rarely applied. Between 1972 and 1991, no school lost a single dollar of federal funds because of sex discrimination. The situation is much the same today. (Sadker & Sadker, 1994, p. 36)

Along with federal laws passed to abolish sexism in education, the government supported grants and programs aimed at increasing female participation in science from kindergarten to graduate school and beyond (Rosser, 1990). In 1980, the Science and Technology Equal Opportunities Act passed thus requiring the NSF to collect and analyze data on the status of women in SMET and create biennial reports for Congress. Soon after and still today, the NSF began funding programs such as (following a chronology); Visiting Professorships for Women, Graduate Fellowships for Women, Career Advancement Awards for Women, Research Planning Awards for Women, Faculty Awards for Women Scientists and Engineers, Model Projects for Women and Girls, and Experimental Projects for Women and Girls. Rosser (1997) describes these initiatives on a continuum, explaining how early programs attempted to add and support women in the sciences and while latter focus more on systemic changes.

Presently, college science education is at an important juncture, that is, whether to adopt and implement reformist epistemology/pedagogy throughout our nation's science, math, and engineering departments or to continue to educate students as it has for the past 300 years. A small number of colleges and universities have chosen the former and revising and reforming undergraduate SMET courses and programs have been underway for at least the last decade. Well funded efforts exist to reform first year engineering courses as well as programs in physics, calculus, and chemistry (Rosser, 1997). Impetus to affect change in the values, beliefs, and pedagogy of science faculty toward a feminist perspective of science are also occurring nationwide but on a relatively small scale (Bianchini, Whitney, Breton, & Hilton-Brown, 1999; Mayberry & Rees, 1997; Rosser, 1997; Roychoudhury, Tippins, & Nichols, 1995). Those efforts modeled on the science reform initiatives of the early 1990s (AAAS, 1993; NRC 1996 b; NSF; 1996) have positively impacted undergraduate students' learning of science (Falconer, Joshua, Wyckoff, & Sawada, 2001; McGinnis & Watanabe, 1996; Yuretich, Khan, Leckie, & Clement, 2001). Studies of these initiatives have shown that test scores have improved along with student attitudes toward science. The participation of females in SMET is improved through efforts such as these. How do we keep them?

Much work has been done to understand the experience of females in SMET in higher education institutions (NSF, 1996, 2000; Sandler, 1996; Seymour & Hewitt, 1994; Thom, 1998; Tobias, 1991, 1992) and the workplace (Davis, 1999, 2000; Eisenhart, Finkel, Behm, Lawrence, & Tonso, 1998). Tobias' (1991, 1992) work has found that female discontent with undergraduate SMET education is the result of poor teaching and curriculum implementation. Female undergraduates choose non-SMET majors or switch out of SMET for a variety of complex personal, structural, and social reasons. A summary of the literature (cited above) explains that, unrelated to talent and interest, women leave SMET because they find the teacher, classroom environment, or subject; impersonal, unmotivating, chilly toward females, too competitive, unwelcoming, unsupportive (academically and with work-home life responsibilities), without role models or mentors, devoid of relevance and interdisciplinary connections, and lacking female representation. Specific examples concerning the issue of relevancy can be found in the following quotes from females in a popular Earth science course (Weiss, 2001). Here we see a confounding disconnect that exists between students' perceptions of their learning and its relevance to their lives.

> It's an interesting course, but the information is not important to me because I don't need it in my career. (Hotel/restaurant management major)
>
> Many of the things are relevant... but it seems in this day in age, knowledge about nature is not necessary, unless you are a specific type of scientist. (Psychology/Elementary Education major)
>
> The course was not personally relevant beyond the fact that I had/have a personal interest in the subject. I have no idea how it may impact my future. (Business major)
>
> [The course] helped me to get my gen-ed requirements, and I learned a bit... which although it may not be terribly useful knowledge for my line of work, it is interesting." (Elementary education/communications major)

These quotes implore us to focus research on teachers' values and beliefs and how they foster or impede an equitable learning environment. The question then arises, "How can science education change to transform the scientific community of practice by broadening the notion of legitimate participation and who can attain it?" Approaching this question requires a critical perspective concerning the nature of the phenomena (Freire, 1971; Giroux, 1992, Gore, 1993) and an understanding of the arguments and proposals for the transformation of science education (Apple, 1992; Brickhouse, 2001; Harding, 1994, hooks, 1984, Keller, 1996, Lather, 1991; Rodriguez, 1997; Schiebinger, 1999). Chapters 1 and 2 of this proposal inform these issues.

Statement of the Problem

Attaining scientific literacy for all and affording all opportunities to legitimately participate in science is complex and dependent on many factors. Presently, not everyone is scientifically literate nor afforded equal opportunities to connect with science in meaningful ways. While females have made gains in some SMET fields, gaps still exist. Teachers hold one of the many keys to ameliorating these inequities.

Determining the conditions necessary to initiate teacher change toward the adoption of an inclusive pedagogy for science is critical if we are to continue to disrupt the existing inequalities. Little research exists that is relevant to such a determination for higher education. This study adds to the research gap by exploring the role that professors' values and beliefs play in successful reform of science education. Furthermore, it offers and reflects on a treatment designed to foster teacher change toward the adoption of a more inclusive pedagogy.

Purpose of the Study

> A belief that all students can learn – the commitment must be more than rhetoric and good intentions. If we assume that all students can learn science, then we must ask about attributions and opportunities when students do not learn. We will no longer blame students. Any attribution of blame must be shared by professionals in the education system. (Bybee, 1997, p. 195)

The primary purpose of my research was to explore, describe, and analyze the conditions necessary to foster change toward a more inclusive pedagogy by professors of introductory level science courses.

A second purpose was to inform teacher change research through the use of a methodology (see definition for assisted action research) that provides professors opportunities to deeply reflect on and engage in critical discussion about the values, beliefs, and personal/contextual factors that constrain inclusive practices.

A third purpose of the research was to inform higher education professional development efforts for college science teachers by asserting the conditions of teacher change toward an inclusive pedagogy.

The major questions of my study were: "How does placing the professor in a position to conduct an assisted action research project help to foster teacher change conditions?" "How do the practical theories guiding the professors' teaching foster or impede inclusionary practice?" "What necessary conditions of the teacher change process toward an inclusive pedagogy emerged from my study?" I was guided by issues such as, "What is going on in this case?" "What deeply held values and beliefs guide actions, interactions, and activities?"

Significance of the Study

Many are calling for research into what guides a science professor's pedagogy in order to understand the potential for reform (Astin & Astin, 1993; Gess-Newsome et al., 2001; NSF, 1996; Rye & Dana, 1997; Tobin, Tippins, & Gallard, 1994). Rye & Dana (1997) determine that studies "conducted on science education reform in elementary and secondary school settings suggest that the attitudes, beliefs, and practices of college science faculty, as well as the culture of their university classrooms, require serious attentions as they have strong implications for the reform of post-secondary science education" (p. 2). According to Bianchini et al. (1999), "science education reform efforts need to go beyond the reform of content and course structure (contextual factors) and attend to the importance of challenging and changing the beliefs of the educators themselves" (p. 37). They recommend that scientists "look more closely at the intersection of views of students, classroom practice, and the nature of science...[and] develop their own response to equity issues from their experiences...[to] help create a more just and equitable science education for us all" (p.34). Further, Hashweh (1997) asserts the need for studies that "carefully describe how specific and well-conceptualized beliefs affect specific teaching behaviors…" (p. 48) and "ask how… beliefs develop and how resistant or amenable they are to change"(p. 61).

The significance of this study to science education reform is that it accompanies the suggestions from educational research base with an attendance to the voices of those traditionally "acted upon" by most reform efforts. By carefully documenting and describing the experience of the professors engaging with the researcher in sustained collaborative conversation about their practice and by positioning student reflections at the center of those conversations, my study focused on a teacher change process that is fueled by the needs and reflections of those most affected by reform efforts.

A major emphasis of teacher change research has investigated how teacher attitudes and beliefs guide practice and the ultimate adoption of different and/or reform-minded teaching practice (Lederman, 1992) and the conditions necessary for teacher change (Lyons, 1990; Schon, 1983; Shulman, 1987; Liston & Zeichner, 1991). Little research has been conducted that focuses on transforming, as (Lave, 1988; Lave & Wenger, 1991) state, "identity-in-practice" within a learning environment. Such a transformation requires understanding that learning is situated and evolves (Wenger, 1998). This study offered a unique and in-depth look into the attitudes and beliefs guiding practice *through lived experience*. It probed critically into the practical theories guiding teachers' adoption or rejection of inclusive pedagogy as they occurred. Because of this, the study's conclusions were based on the "voices" of the professors as they reflected on authentic activity. If this study were not conducted, the teacher change literature would continue to lack an understanding of the unique relationship between culture, identity, and the day-to-day personal and contextual factors that influence the adoption of an inclusive pedagogy.

We know from the literature that teachers' actions in the classroom exert great influence on female interest and achievement in science and math (Rennie & Dunne, 1994; Kahle & Meece, 1994; Sadker & Sadker, 1994; Rosser, 1990, 1997). This study is significant from the perspective of female students as it placed their reflections on interest and achievement within the teacher change process. Student participants had a unique opportunity for making their ideas as non-science majors known.

A potential outcome of this process was the adoption of an inclusive pedagogy by the professors, enabling students to engage in inquiry-based, authentic learning experiences (AAAS, 1989, 1993; Rosser, 1990, 1997; Sandler, 1996; Tobias, 1992). Inherent in the enactment of an inclusive pedagogy is an explicit critical understanding of the role of power in the classroom and the significance of alternative discourse practices. Transforming traditional classroom hierarchies and discourse routines offers females a more "female friendly" (Rosser, 1990) learning environment.

Fenstermacher (1979) proposes the presentation of research findings to teachers "as evidence… to encourage the transformation of teachers' beliefs…" (p. 169). Utilizing action research as a methodological strategy responded to the suggestions of educational researchers conducting studies of teacher change (Gess-Newsome et al., 2001). My study created an arena for critical reflection by and for the professor. This was important as many novice action researchers lack this perspective (Feldman, Rearick, and Weiss, 2001).

My hypothesis for the study was that if a professors experience dissatisfaction with their pedagogical beliefs and actions they will have met the conditions necessary to change them (Feldman, 2000; Gess-Newsome et al., 2001). Creating the conditions necessary to instigate change in professors' pedagogical actions and beliefs occurred as they reflected on students' thinking. Though allowing for open-ended reflection, my research positioned the conditions necessary to instigate change within the realm of feminist and social justice issues for teaching and learning.

The roles to be studied were those of the students and professors in a reformed college level introductory science course. Within each role, I was interested in studying the context of their action (teaching or learning) and the role of identity as it interacted with the context. Additionally, I explored the interplay between reflection and action and specifically how students' reflections of learning offer a mirror through which the professors reflected on and changed their actions in the classroom.

Specific Considerations

Assumptions

Four assumptions guide this research. First, that the teachers in my study were interested in issues of teaching and learning. Next, that the teachers would deliberately reflect on the their practice assisted by the action research design of the study. Also, that incorporating a critical perspective into the teachers' reflection would motivate reflection about inclusive practices. Finally, that reflection on their practice would lead to teacher change.

Limitations of the Study

There are two possible limitations to the study. First, my close collaborative involvement in the professors' reflection of their practice may have influenced my ability to collect and analyze student data about teaching and learning in the course. Assuming the role of critical friend and facilitator required extreme attendance to reflexivity, namely, my own examination of the "interplay of [my] own personal biography, power, status, interactions with participants, and written word" (Rossman & Rallis, 1998).

Another limitation relates to the teacher change intervention imposed upon this study. The study utilized a highly intensive participatory research strategy that, by its very nature, fostered some degree of teacher change. How useful can these findings be to reform initiatives? How realistic is it to "assign" a critical friend to each participant in a reform project?

In addition, sample selection limits the study. The study investigates teacher change with professors already committed to changing aspects of their practice and only two scientists were involved in the research.

Finally, the amount of time I was able to spend with each professor during the study and the overall length of the study is a limited factor. Further research will more successfully determine the lasting effect of the assisted action research projects on their practice as teachers.

Definitions of Terms

Alternative discourse practices – can be linked to Hildebrand's (1998) description of "Hybrid imaginative writing [that] includes any blended genres that use scientific and/or factual genres (recounts, procedures, reports, explanations, expositions, discussions, etc.) in conjunction with imaginative or fictional genres"(p. 347).

Assisted action research– means facilitating and promoting teacher research, it includes engaging the teacher in collaborative sustained conversations that are critical and supportive of the self-reflexive process of systematic, critical inquiry made public (Stenhouse, 1975).

Collaborative sustained conversation - "a conversational exchange in a particular situation that relies on the teachers' expertise and experiences" (Feldman, 1998, p. 5)

Conditions necessary to facilitate pedagogical change - is generally defined as conditions creating pedagogical dissonance for the professor (Feldman, 2000)

Critical friend – a trusted person who asks provocative questions, provides data to be examined through another lens, and offers critique of a person's work as a friend. A critical friend takes the time to fully understand the context of the work presented and the outcomes that the person or group is working towards. (Costa & Kallick, 1993)

Inclusive pedagogy -"acknowledges the cultural specificity of science and empowers our students to engage in science constructively" (Brickhouse, 2001, p. 283)

Meaningful learning – learner merges new concepts and images with previously acquired knowledge; requires employment of metacognitive learning strategies; produces useable knowledge (Novak& Gowin, 1984)

Practical theories - originate from experience and ethical and moral lessons, act as "rules of thumb" and offer teachers reason and rationalizations for the choices they make in the classroom (Feldman, 2000) .

Starting points (of the Action Research Project) – issues in the teacher's practice that are able to be studied over time and chosen primarily because they are worth studying to improve practice, but also take into consideration if the issue is feasible to study with respect to; 1) researcher's capabilities, 2) available resources, and 3) the potential for fruitful findings (Altrichter, Posch, & Somekh, 1993).

Teacher and curriculum centered instruction – teacher is central authority figure in classroom who holds all the knowledge and voice, determines how students will learn, and structures all activities. (Cuban, 2000)

Chapter Overview

Chapter One of this paper presented an argument for the enactment of more inclusive practices by science teachers. I describe the current situation of female experience and participation in science and, using the literature, explain why teacher change toward an inclusive pedagogy is necessary if we are to meet the challenge of "science for all". In this chapter I also framed the role of college science teaching in this effort and briefly described my methodology aimed at exploring science professors' teaching practice and the potential for teacher change.

My literature review follows in Chapter Two. Here, I cite and explain the literature base that guides and frames my study. In three sections I overview; scientific literacy and feminist perspectives on national efforts toward reforming science education, the marginalization of groups and influence of culture in science education, and perspectives on teacher change and how to transform science education.

Chapter Three presents the methods of my research. In this chapter, I present the overall approach and rationale for the study and state its major questions. I then describe the setting and its participants followed by my data gathering and analysis procedures. Methodological limitations of my work are considered.

In Chapter Four, I present an in-depth description of the context of the research study. Using fictionalized narratives and "thick description", I describe the teaching context (structural and cultural), personal characteristics of the professors, and their thinking on issues of teaching and learning.

In Chapter Five, I describe in detail the assisted action research projects that were conducted. Interwoven in my characterization are glimpses of analysis that emerged during that portion of the research.

In Chapter Six, after characterizing the nature of the assisted action research projects, I describe the practical theories that informed the professors' practice and consider inclusive practices.

In my concluding Chapter Seven, I revisit the context of the setting to make sense of the professors' interest and stance toward issues of an inclusive pedagogy and asserts necessary conditions of the teacher change process that emerged from my study.

CHAPTER 2

LITERATURE REVIEW

The intent of this literature review is to provide theoretical knowledge and expository notions about science education reform. More specifically, it unpacks the idea of scientific literacy and what achieving it for all citizens means for our citizenry in general, and science education, in particular. The call to reform science education has been heard and acted upon at the college level where this study took place. From a feminist perspective, what does a reformed equitable introductory level science course look like? How can it be achieved? This paper attempts to answer those questions by exploring the ideas and theories behind scientific literacy, feminist theory, the nature of science, the marginalization of groups by the scientific community of practice, the role of identity, situated learning theory, teacher thinking and change, and inclusive pedagogy.

My review is presented in three sections, Section I: Science Literacy and Current Initiatives in Science Education, Section II: Marginalized Groups and the Role of Identity in Science Education, Section III: Inclusive Pedagogy and the Transformation of Science Education.

Section I, Science Literacy and Current Initiatives in Science Education presents national "mainstream" efforts to achieve scientific literacy and criticisms of such efforts by feminist theorists and others in the educational research community. It offers arguments made for greater inclusion of nature of science issues in science education. The section also summarizes current programs designed to meet national standards as well as programs deemed inclusive/effective by mainstream critics. The section is important to understanding the history and sociology of national reform efforts and their place in maintaining the status quo of who can participate in science. It situates the reform effort that the professor participants in my study are affiliated with and describes the culture of mainstream science education reform.

Section II, Marginalized Groups, Culture, Community, and Science Education considers the nature of the marginalization of females and people of color by the scientific community from a social justice standpoint. It summarizes the perspectives of social justice, feminist, and critical theorists as to the roots of the phenomena and how it is maintained in society. It offers a framework through which to consider how social identity forms and impacts individuals' conscious and internalized beliefs about their role in society's hierarchical power structure in general and science in particular. It considers how students, especially females, develop a "science " identity and how that identity impacts learning and attitudes toward science. Situated learning theory is advanced as a lens to view and understand the multiple and multidimensional factors impacting group and individual inclinations toward science and learning. The section informs my research study by illuminating what the research base asserts about female identities and participation in the scientific community of practice. Along with Section I, Section II sets the stage for an informed discussion of the transformation of science education in Section III.

Section III, Transforming College-Level Science Education, drawing on the conclusions of previous sections, presents proposals for the transformation of science education from a feminist perspective. Critical to the change scenario is an understanding of how and why teachers change their practice. A review of the literature relating to teacher thinking is presented. Highlighted in the piece are research projects, theories, and ideas from the teacher knowledge base, sociocultural, and teacher reasoning perspectives. These perspectives offer insight into how and why teachers develop their pedagogical content knowledge [PCK], beliefs and values and why teachers are slow to change their practice. Understanding the how and why of teacher change is offered through Feldman's (2000) model of practical conceptual change. Following that, the section presents inclusive pedagogy [IP] as the pedagogy of choice for equitable and meaningful reform of science education. Drawing on theories and notions from previous sections regarding situated theory, identity, and sociocultural and structural factors, the section presents an overview and indicators of IP. The conceptual foundations of inclusive pedagogy and its characteristics are presented and substantiated by the research base. Examples of inclusive pedagogical strategies used by professors of reformed science courses and the impact of those strategies on students' conceptions of science and teaching are described.

Section I: Science Literacy and Current Initiatives in Science Education

Consensus exists in the scientific, educational, and general community that *all* students should be scientifically literate upon high school graduation, and especially by college graduation.

What does it mean to be "scientifically literate"? How do we achieve that goal? Why do feminists assert that science is not yet for all?

The notion of scientific literacy is not new nor is it easily defined or achieved. Moreover, regardless of how one conceives of it, on some epistemological level, whether for political and/or moral reasons, we agree that it is a good thing, a right thing, and a valued thing for our citizenry. Perhaps this is because of a basic resolution of our democratic ideology, namely, that all citizens should be able to contribute equally in important societal decisions (Nelkin, 1975). Perhaps science education researchers and curriculum developers promote science literacy because they are liberal-minded skeptics who fear that the average person will get duped and disenfranchised by the rapidly strengthening marriage of science/technology to politics/development and media. Or maybe its advocates just need the funding. Some assert that our capitalist system requires scientific literacy for economic advancement (Apple, 1992; Fenstermacher, 1994). This chapter intends to illustrate and understand what the educational research literature says about scientific literacy and science education reform, and to offer a pathway through the research to posit an equitable and practical definition of the term from a feminist perspective. Such a definition will be used to construct an inclusive vision for science education reform at the college level. I begin by framing my argument that, reformed or not, science and science education tend to operate within very traditional boundaries of thought and activity thus prohibiting equitable participation by all members of our society.

Defining Literacy

Literacy, as a term, has historically been applied to one's ability to read, write, listen, and speak. Functional literacy (Venezky, 1990) is a term used by the Literacy Volunteers of American (LVA) who work toward enabling citizens to use reading, speaking, writing and computational skills in their daily lives. This perspective on literacy is aimed at the adult population who are expected to navigate their way autonomously in society and focuses on knowledge and skills. According to the LVA (1993), as much as 23% of our population is functionally illiterate and an additional 28% function at the lowest level. While LVA members take committed action to improve individual's lives, it seems that mainstream references to functional illiteracy focus more on how it damages society (Apple, 1992).

Scribner (1986) offers three metaphors for the purposes of understanding the term literacy. Through these metaphors we see an extension of the more common notion of functional literacy. She defines functional literacy as adaptation, that is, the ability to develop proficiencies toward effective functioning in the world. Here she stresses the individual nature and inclination of such proficiencies. Next, she promotes literacy as power, meaning that with literacy comes the power groups need to speak, be listened to, and secure a just place in the world. Her final metaphor likens literacy to a state of grace – focusing on the personally favorable potential of being literate and how it affords an individual special attributes. This can be likened to achieving legitimacy within a community of practice (Lave & Wenger, 1991). These metaphors challenge us to envision literacy in three separate and connected dimensions, that is, what is good for individuals/society, what is good for our social group, and what is good for ourselves. Inherent in this challenge is a critical perspective regarding what it means to be literate, who defines literacy and who benefits from such a definition. Keeping these metaphors in mind will aid us in our consideration of a term at the heart of my research interests, scientific literacy.

Scientific Literacy

LVA-defined functional illiteracy, though determined when one is an adult, is often traced to ineffective schooling – a link applied to scientific illiteracy as well (Kyle, 1995).

The term "science literacy" is credited to Paul DeHart Hurd (1958) and Conant & Watson (1952) over forty years ago. However, historical perspectives reveal that a synonymous idea has existed in educational literature since about the mid-19th century (Bybee, 1997; Deboer, 2000; Shamos, 1995). Additionally, Deboer (2000), through continued research of the history of the term and its meanings states that numerous goals for scientific literacy have appeared since the 1950s. All the goals share a focus on students' knowledge and development of science concepts and processes yet may situate learning within different curricular perspectives. Such perspectives include, for example, science and technology, science and society, the nature and history of science, and cultural and aesthetic understandings of science.

Bybee (1997, p. 46) heralds scientific literacy as the "fundamental goal" of science education. However, no one definition of the terminology has been embraced by all involved in the cause.. What it means to function in a scientifically literate fashion is under debate, at minimum it entails; 1) understanding scientific and technologic developments, 2) engaging in informed discourse, reflection, and decision-making about such developments from a personal, ethical, social, and political perspective, and 3) demonstrating scientific attitudes and behaviors such as, for example, the ability to engage in scientific inquiry (AAAS, 1989; Bybee, 1997; Jenkins, 1990; Champagne & Lovitts, 1989). If we look hard at the above explanation we can tease out Scribner's metaphors of adaptation, power, and state of grace – but they are not obvious. Her ideas of power and the personally unique and meaningful definition of literacy are, at best, mildly implied.

Much of the on-going debate about the definition of scientific literacy centers on its various parts, namely, knowledge, skills, and attitudes. In general, *knowledge* refers to understanding and the ability to properly apply key science concepts and facts. *Skills* have to do with scientific inquiry and one's facility in using the methodologies of science in scientific activities and everyday problem solving. *Attitudes* brings in the popular yet deceptive attainment of learning about the nature of science that allows students to be critical informed consumers of mainstream scientific knowledge. Additionally, it includes empowerment and self-efficacy (Bandura, 1986; Hungerford & Volk, 1990; Rowe, 1983; Rubba & Weisenmayer, 1988) and the ability to transform what it means to participate "legitimately" in the science community (Davis, 2001; Lave & Wegner, 1989; Lather, 1991; Brickhouse, 2001; Harding, 1991). These dimensions of scientific literacy are, in a way, summary definitions of the major components of the nature of science (NOS) that more deeply and descriptively define scientific literacy.

Lawson (2000) states that no consensus exists concerning scholarly understanding of the nature of science. Felske, Chiappetta, & Kemper (2001) concede that though a universally accepted definition of the scientific literacy is futile "one aspect of science education that is agreed upon is the essential role that the nature of science (NOS) plays in the development of scientific understanding" (p. 2). Evidence for this claim is discussed below.

The NOS can be described through its five critical components; 1) the purpose of science, 2) methods of science, 3) the history of science, 4) the philosophy of science, and e) sociology of science (Felske et al., 2001; Lederman, 1992; Lawson, 2000). According to Felske et al. (2001, pp.3-4):

> The purposes of science focus on how scientific knowledge is generated, validated, and revised in an attempt to understand nature. The scientific enterprise engages in the study of nature so that humankind can explain the mechanism of events and predict those events with great accuracy. Science's primary missions are to develop a body of fundamental knowledge and to apply that knowledge to society.
>
> The methods of science are intimately related to its progress and success. The investigative methods and experimental techniques used by scientists to learn about biological and physical phenomena aid them in figuring out their complicated mechanisms. Asking questions, making careful observations, forming insightful hypotheses, devising techniques, and conducting clever experiments are among many ways scientists go about their work. The techniques and apparati used to carry out investigative procedures and collect data are as important as the generalizable methods.
>
> Science is an on-going changing enterprise and reflects its history. Science is a human endeavor and the history of science is essential to understanding how the scientific enterprise and scientific knowledge came to be. Acting as a repository of knowledge, the history of science illuminates the multitude of methods and inquiry procedures scientists use to generate scientific knowledge. It also highlights the human aspects and role that science has played in the development of various cultures.
>
> The philosophy of science examines questions that arise from reflecting on the nature of science. Philosophy of science questions are *about* science. These questions analyze the modes of inquiry, the ethics involved in decision-making, and the construction and assessment of scientific knowledge claims. The philosophy of science makes us think about the processes, reasoning, and investigative methods scientists employ in their search for knowledge.
>
> The values and beliefs of society impact science. Science cannot insulate itself from society. The sociology of science is responsible for identifying forces that impact knowledge, public awareness and attitudes toward science, the rules and regulations scientists impose on themselves, and the consequences and application of scientific knowledge.

Using these meanings to understand the NOS, Felske et al. (2001) report on research concluding that a high level of consensus exists amongst scholars on twenty-one NOS statements gleaned from two major players in the science reform efforts, the Benchmarks (AAAS, 1993) and the Standards (NRC, 1996a). They conducted multiple staged interviews of five experts who reached an ≥80% consensus on 20 of the statements, indicating that the two documents share definitional meaning concerning components of the NOS. Because definitions of scientific literacy contain dimensions of NOS, this is reported to be good news. It implies that the science education community producing and utilizing these major documents is working under similar conceptual frameworks. Disturbingly, however, Felske et al. found that all of NOS' critical components are not equally represented in the reform documents. The authors conclude that "the Benchmarks (AAA, 1993) and Standards (NRC, 1996a) emphasize the purposes and methods of science more than the history, philosophy, or sociology of science" (p.11). As we shall see, critics of the major reform initiatives' scientific literacy vision, though varied in their rationales and solutions, agree that these omissions seriously jeopardize the realization of "science for all". This is because it leaves subjective aspects of the nature of science most important to teach and may lead to "selective implementation" (Bybee, 1997). It also does nothing to improve knowledge of the nature of science amongst educators. Following a tradition of science education reform, the reform documents under study may lead to "science as usual" curriculum primarily focused on its body of knowledge and methods of scientific inquiry. Females and men of color are yet to succeed fully in science under such a narrow educational emphasis.

Conflicts arise in science education circles in regard to which dimension and components of the NOS should be the focus of curriculum, what successful instruction should look like, what teachers do and do not know about scientific literacy (Brickhouse, 1991; Koulaidis & Ogborn, 95, Lederman & Zielder, 1987), and why science literacy is or is not improving (Abd-El-Kahlick& Lederman, 2000; AAAS, 1993; Bybee, 1997; NRC, 1996a). Consequently, there is not one consensual path to scientific literacy and achieving it means different things to different people. The major science education reform efforts promoted in the early 1990s by the American Association for the Advancement of Science (1993), the National Research Council (1996), and the National Science Teacher's Association (Aldridge, 1992: NSTA, 1992, 1995) offer a notion of scientific literacy that forced many to deeply question and analyze what it means to be scientifically literate, why it is or is not important, and how to achieve it. Because of the huge impact these efforts have had on K-16 science education and its reform, a brief description of these initiatives and their vision of scientific literacy is offered below.

Three Major Science Education Reform Initiatives of the 1990s

In 1983 the National Commission on Excellence published A Nation at Risk. This pivotal work brought the notion of a crisis in science and math education to ears of the public and the work of legislators and has had a huge impact on the reform projects under implementation and analysis. The now famous quote that sent parents, school districts, teacher educators, and government scrambling to "fix" the perceived crisis in education states that:

> Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being taken over by competitors throughout the world... the educational foundation of our society are presently being eroded by a rising ride of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur – others are matching and surpassing our educational attainments. (National Commission on Excellence in Education, 1983, p. 5).

The eighties set the stage for the reform efforts launched at the end of the decade. Today, these efforts not only impact SMET reform at the k-12 level but also are continuing to affect programs and grants aimed at improving college teaching. As such, the efforts have their supporters and detractors. Below I briefly describe two of the major reform initiatives of the last 13 years and specifically cite one higher education reform initiative. Following that I summarize three educational researchers' critiques of the current reform efforts to set the stage for my critical sociocultural perspective of science and science teaching later in the paper.

Science for All Americans (The American Association for the Advancement of Science)

In 1990, Rutherford and Algren published a 264-page description of science literacy known as Science for All Americans (SFAA). SFAA is a culmination of the work by five panels of mostly scientists who determined key recommendations for education reform in the areas of biological/health sciences, mathematics, physical/information sciences/engineering, social/behavioral sciences, and technology. This work lead to the federally funded reform project known as Project 2061 (AAAS, 1989) which has been implemented in school districts in a variety of socioeconomic settings since the late 1980s. The project's goal is scientific, mathematical, and technological literacy for all. Though these literacy's are developed and defined throughout the book's chapters, a concise definition of scientific literacy that touches on the dimensions of knowledge, skills, and attitudes is offered below:

> being familiar with the natural world and respecting its unity; being aware of the some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific thinking; knowing that science, mathematics, and technology are human enterprises; and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal social purposes. (Rutherford & Algren, 1990, p. x)

Along with a definition of SL that promotes knowledge acquisition and use for personal and social uses, SFAA values collaborative sense making by all for the good of society:

> Science education should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent and vital. (Rutherford & Algren, 1990, p. v)

This perspective is further described in SFAA's six principles for Project 2061 in which scientific literacy is the key to solving global and local problems, moving beyond human self-interest, existing in peace with the environment, and achieving a better world. Acquiring intelligent respect of nature, scientific habits of mind, and understanding of technological principles, new technologies, and creative use of technologies will, according to the document, promote these principles. AAAS is continuing to describe and develop its notion of scientific literacy as evidenced by its recent publications - Atlas of Science Literacy (2000) and Designs for Science Literacy (2001).

National Science Education Standards (National Research Council)

Concurrently, the National Research Council (NRC), the research arm of the National Academy of Sciences, published its final version of the National Science Education Standards (1996a). This effort is considered a baseline document by many through which to develop and implement science education reform. The "science education standards provide a concrete expression of national goals and a banner around which reformers rally"(NRC, 1996, p. I-3). The standards have since become the benchmarks for science education teaching and assessment. "Acknowledging its debt to SFAA...NRC adopted a very similar view of scientific literacy" and a "clear commitment to scientific literacy for all" (Eisenhart, Finkel, & Marion, 1996, pp.265-266). NRC's definition of science literacy and description of science for all follows:

The goal of the National Science Education Standards is to create a vision for the scientifically literate person and standards for science education that, when established, would allow the vision to become a reality. The standards, founded in exemplary practice and contemporary views of learning, science, society, and schooling, will serve to guide the science education system toward its goal of a scientifically literate citizenry in productive and socially responsible ways. (NRC, 1996a, p. I-1)

All students, regardless of ender, cultural or ethnic background, physical or learning disabilities, aspiration, or interest and motivation in science, should have the opportunity to attain higher levels of scientific literacy than they currently do. This is a principle of equity…. This principle… has implication for program design and the education system, especially the allocation of resources to ensure that the standards do not exacerbate the differences… that currently exist between advantaged and disadvantaged students. (1996a, pp. I-6-7)

Reform in Higher Education: An NSF Initiative

As this new wave of reform began impacting K12 science education, actions were being taken to improve the learning of science, math, engineering, and technology (SMET) at the college level. AAAS' Blueprints (1997) explicitly cites the need for such change

Higher education has a significant role to play in K-12 education reform. For example, if as reformers envision, the entire K-12 science curriculum is restructured, higher education will have to rethink the way it admits, counsels, and places students; the it organizes it curricula and teaches undergraduate science, mathematics, and technology; and the way it goes about preparing the next generation of school, college, and university faculty. Higher education can support K-12 reform by continuing to explore ways to improve science and mathematics education for undergraduate and graduate students alike. (Chapter 10, pg. 1)

These initiatives, while impacting the reform rhetoric at the K-12 level, further motivated a change in higher education as well. In the early 1990s, the National Science Foundation's (NSF) Division for Undergraduate Education developed a program to improve undergraduate science and math education. Guided conceptually by the AAAS work and specifically by their publication, Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology (1996), the NSF sponsored a grant program known as the Center for Excellence in Teacher Preparation (CETP). Through this program five million dollars were awarded to K-16 Collaboratives, headquartered at major universities, to improve the teaching and learning of SMET with the ultimate goal to improve teacher education programs. Presently, thirty-two "system-wide focus" and "institutional focus" grants have been awarded nationally.

In general, the CETP collaboratives share common goals, namely to 1) reform undergraduate SMET content courses in order to focus on core concepts and make relevant connections between SMET, and 2) infuse instructional and assessment strategies into the teaching of SMET content courses from a constructivist perspective (McGinnis. & Watanabe, 1996). With respect to the latter, they consider and apply conceptual change theory, promote metacognition, and emphasize critical thinking and inquiry over rote memorization of facts as student outcomes (Cobb, 1988; Driver, 1989; Tobin, Tippins, & Gallard, 1994; von Glaserfeld, 1987). These initiatives have labored hard to illuminate and extend SMET faculty's pedagogy with the hope of decreasing lecture and adopting a more student-centered and problem-solving approach to college teaching.

A major mechanism utilized in achieving the vision of scientific literacy embedded in the reform initiatives just described is the reduction of teacher-centered and content-rich lessons and an increase in student-centered inquiry-based learning environments. Gess-Newsome et al. (2001) describe the effort to implement such a mechanism as one "[requiring] fundamental changes in both teacher thinking and classroom practice" with the purpose of "[challenging] the cultural tradition of schools" (Romberg & Price, 1983, p. 159, in Gess-Newsome et al., 2001, p. 3). As expected over time, a number of educational researchers have supported and/or expanded the conception of scientific literacy and the practical issues surrounding its achievement (Bybee, 1997). Others have heavily criticized the underlying goals and implementation vision and assumptions of these efforts.

AAAS, NSTA, NRC Notions of Scientific Literacy and Educational Reform: Misguided, Mythical, & Narrow?

Hurd's Critique

Hurd (1994) believes Science for All Americans (AAAS, 1989) and the National Science Education Standards (NRC, 1996a) have lost vision. He criticizes (1994, 1997) these initiatives by stating that they have not kept up with researchers' deeper understanding of scientific knowledge, its holistic nature, and inextricable relationship to technology. Also, about 75% of science research conducted today is strategic in nature versus academic. This means its focus is on projects designed to benefit human well being or social or economic progress. In his view, the goals of current science education reform efforts are not situated similarly but remain entrenched in an academic focus. A disappointing outcome, he believes, because the reform literature stresses a more public, socially responsible understanding of science. Hurd is arguing that even though AAAS and NSTA have set reasonable goals for scientific literacy, the resultant educational policies stem from a "problem approach" that have misdirected the focus of reform. Instead of educating students for responsible citizenship, "piecemeal" solutions, such as, up-dating subject matter in the individual disciplines, re-arranging courses to better suit students' developmental needs, increasing the numbers of science courses students and teachers must take, increasing "time on learning", broadening the role of the principal, and increased use of high-stakes testing are being offered and implemented. Nationwide school districts are focusing on these so-called "solutions" instead of re-conceptualizing what students need to know to become scientifically literate.

Hurd believes we could achieve scientific literacy through a new conceptualization of the science curriculum. He was one of the first to offer the notion of scientific literacy contemporary phraseology and has enhanced his definition over time (1994, 1997, 1998). To him, scientific literacy means acquiring knowledge that leads to students' well-being and resultant responsible citizenship. His book, Inventing Science Education for the New Millennium (1997) places the goal of science literacy deep within the perspective of technology and biology understanding and appreciation. His vision requires a deep understanding of our "science and technology oriented democracy" and "knowledge intensive society." This can be accomplished through a "lived curricula" for education whereby students' lives, communities, and futures are accommodated in the science/technology curriculum along with opportunities to succeed at logical reasoning, problem solving, and decision-making within a social and biological context. He agrees with current reform initiatives that emphasize attainment of higher order thinking skills, but argues that these skills "are related to optimal use of science knowledge in personal and social contexts…[and are] qualitative in nature, in contrast to the notion of scientific inquiry, which is quantitative and discipline bound" (p. 17). His proposed curriculum is interdisciplinary and is derived from 14 randomly selected themes; health, environment, learning/information processing, biotechnology, risky behavior, biological system optimization, decision making, understanding others, adapting to change, strategic research, life skills, knowing oneself, real life problem solving, and quality of life.

I find Hurd's ideas, though seriously lacking critical analysis on the why and who of the scientific enterprise and science teaching, intriguing and pragmatic. I believe his explanations and literary citations in regard to how career scientists are trained and contemporary science is practiced bear out the need to reform aspects of the knowledge base and pedagogy of not only K12 science curriculum but higher education as well. His frustration with current reform documents is not unreasonable. He deeply understands the power of large federally funded education reform machines and questions their underlying motives. Unlike the higher education science curriculum that is most often uniquely designed by individuals or small groups of professors, K12 science education is somewhat more malleable. Because national reform efforts impact and guide textbook production, districts' curricular decisions, summer professional development programs, national teacher conferences, and Schools of Education, Hurd wonders why they have not stressed the more personally relevant and socially-minded agenda that clearly exists in the reform language. This relates to how Hurd conceives of the nature of science's critical components. To him, the reform efforts promote learning about the purposes and methods of science within an academic context. In this latest work, he stresses not only changing their substance but also situating them within contemporary understanding of the sociology and philosophy of science. In my view, he envisions a project approach to learning that engages students in issues personally relevant to their life experiences. Students learning about risky behavior, for example, may study a unit on AIDs. Students would work in teams to understand AIDS (how it is diagnosed, monitored, and treated) and how technology has advanced and changed our knowledge of the disease. An outcome of this team approach would benefit the students' school and community. Stressing the history of science does not seem to be an important piece of Hurd's science education plan. For example, I don't believe he would expect the curriculum to reflect issues of gender inequality with respect to the protracted action of the medical community to the impact of AIDS on females.

He doubts that current science education efforts will aid us in achieving scientific literacy – but he does share its vision. Morris Shamos, a physicist and educator, on the other hand, finds the notion of scientific literacy irrelevant.

Shamos' Critique

Morris Shamos, in his book The Myth of Scientific Literacy (1995) writes:

> The current state of science education, as well as most of its problems, is clearly influenced by a single overriding premise: the primary function of formal science education, whether precollege or college, is to ensure a steady supply of scientists and science-related professionals, including, of course, science educators. Everything else that is done in science education, regardless of its education worth or numbers of students involved, turns out to be secondary to this goal. (p. 73)

> It would be different if science education for the general student were justified solely on the grounds of a cultural or intellectual imperative… p. 75

Agreeing with John Dewey's hope for science education, that is, to create "scientific habits of the mind" and promote social literacy, Shamos considers current reform initiatives seriously flawed in their ultimate intent. He believes that the reform efforts of NSTA and AAAS have based K12 curriculum on an academic college curriculum model and are therefore asking "What should be taught?" rather than "Why should it be taught?" His "true" definition of scientific literacy does not require knowing facts, laws, or theories nor having advanced mathematical skills. Instead, it requires knowing something about the overall scientific enterprise. This means being aware of some of science's major conceptual schemes, how and why theories were created and accepted, how science orders the universe, and the role of experiments. Shamos (1995) writes, a scientifically literate person "appreciates the elements of scientific investigations, the importance of proper questioning, of analytical and deductive reasoning, of logical thought processes, and of reliance upon objective evidence" (pp. 89-90).

By denouncing mainstream efforts at scientific literacy as fallacious, Shamos is criticizing four basic assumptions embedded in the reform literature. First and foremost, he argues that knowing academic formalized science as a student does nothing to guarantee real scientific literacy as an adult. "Good school performance, even a reasonable level of scientific literacy while one is a student, provides no assurance that the individual will retain enough science when he or she becomes a responsible adult" (pp.74-75). He cites evidence for this in the continued cry for scientific literacy that has resounded, and ultimately resulted in waves of science education reform, since the nineteenth century. Yet, although a large part of our population have experienced education under these reform efforts and value science for its technological achievements, only 5% are scientifically literate. Secondly, he disagrees with the Standard's (NRC, 1996a) premise that scientific literacy deepens throughout one's life and feels the reverse is true - that students lose interest in science over time (NYAS Seminar Series, 1996). This occurs because science becomes too difficult to understand, is not taught well, and students observe adults living fulfilled lives without science. He also counters with statistics, arguing that approximately 25% of students fail to graduate from high school. Next, he doesn't believe the average person can possibly understand science well enough to conduct "personal independent decision-making" on contemporary social concerns such as pollution, toxic wastes, acid rain, nuclear power, depletion of natural resources, animal experimentation, genetic engineering, and the greenhouse effect. Nor does he feel that it is prudent to expect them to. He states that "so many of the science based societal issues are emotionally burdened, which often moves them out of the arena of reasoned debate..."(p. 91). Lastly, because so many around us have succeeded without science, he believes that students and adults have little genuine interest in scientific literacy. The job market does not really need scientifically literate employees nor does it make everyday living better, our technology is created to be "idiot proof" and we rely heavily on government "to protect us from unsafe or hazardous equipment, foods, health practices, and quack remedies" (p. 93).

Interpreting scientific literacy as a cultural and practical imperative, Shamos believes it should encompass an awareness of how science and technology interact, what science is about, what can be expected from science, and how the public can be heard by scientific experts and visa versa. His estimation of what is important to teach with respect to the NOS differs dramatically from current reform literature. Offering 18 topics for the general science curriculum that are "more realistic" than the NRC standards (focusing on specific discipline-based knowledge) we more clearly see the gist of his message. His topics cover; the purpose of science, the purpose of technology, are science and technology necessary, the meaning of scientific facts, the meaning of scientific truths, the role of theory, the role of conceptual schemes, role of experiment, role of mathematics, complementary roles of science and technology, the history of science (especially technology), cumulative nature of science, horizons of science, its potential and limitations, threat of the anti-science and counterculture movements, societal impacts of science and technology, role of statistics, role of risk-benefit analysis in decision-making, and proper use of expert science advice. Here we can see Shamos highly stressing the history, philosophy, and sociology of science. My understanding of this focus is for high school graduates (very few of whom will learn any more formal science) to be aware of science's impact on their life and enable them to make decisions on scientific issues by effectively utilizing experts. Alternatively, current science education reform efforts, through their continued promotion of the academic purposes and methods of science in order to prepare future scientists for the job market are inherently unable to achieve science literacy for all. Shamos believes the efforts are delusional and are missing a message society has sent since the Enlightenment, that is: "Give us the useful end products of science, but don't expect us to learn basic science" (NYAS Seminar Series, 1996). Sharing yet broadening what is problematic about current reform efforts, Eisenhart, Finkel, & Marion (1996) broaden the scope of criticism by considering what happens in the classroom as teachers "give " and students act on scientific knowledge.

Eisenhart, Finkel, & Marion: A feminist critique

Eisenhart, Finkel, & Marion (1996) re-examine the conditions necessary for scientific literacy. Though supportive of the rationales and goals for scientific literacy presented by AAAS, NSTA, and the NRC, they criticize the narrow expectations of project implementation. "While the proposals envision democratic, socially responsible uses of science and participation by many and diverse people, the existing guidelines do not address obstacles known to interfere with socially responsible applications or widespread interest and access" (p. 266). The authors criticize implementation guidelines and expectations.

Since at least the efforts of the 1960s, science education reform has focused on producing scientists and citizens with scientific knowledge. Current initiatives call for a wider definition of scientific literacy, one that reaches all people and is relevant to the lives of students in a socially responsible society. Eisenhart et al. share with Hurd (1997) and Shamos (1995) the belief, however, that the endpoints of past initiatives and today's are really still the same, to produce knowledgeable people that behave as scientists. Though the means to this end may have changed, for example, the learning of facts has become the comprehension of concepts and teacher directed activities are now opportunities for students to behave as scientists, teachers are not being held accountable for much besides increasing student knowledge. Again, we see criticism of the emphasis on teaching traditional science knowledge within the nature and methods of science domains.

Eisenhart et al. suggest that reform documents lack direction for teaching or assessing learning in the realms of the history, philosophy, and sociology of science. More specifically, the authors discuss that teachers do not know how to teach about the personal and social purposes of science, using science responsibly, or gender inequities. Implied in the reform literature is that student comprehension of these issues will occur implicitly through content and process laden activities. With respect to gender inequities, little effort has been made to critically question the status quo of science and science education as implementation efforts employ a deficit model to allow all to meet certain standards. Eisenhart et al. view this as a result of the chosen conservative posture taken around gender inequities in science. Such an approach, using Keller's (1982) continuum through which to understand critiques of science, believes women and minorities have not succeeded in science because they have not been afforded the same opportunities as males. AAAS, NSTA, and the NRC offer "piecemeal solutions" to deal with the supposed problem instead of, as argued by Hurd (1997), reconceptualizing the problem to begin with. In their own words, Eisenhart et al. write, "In essence, the reform proposals suggest that better teaching, higher standards, and sensitivity to student differences can overcome long-standing obstacles to participation. The proposals take no account of feminist or minority critiques of science" (p. 273). A major premise of their critique and a first step in reconceptualizing the problem questions and analyzes contemporary learning theory and pedagogy used by science educators.

A major focus of science teacher pedagogy evident in the reform literature focuses on Piagetian and radical constructivism that promotes individual reflection and learning. This focus supports science curriculum and pedagogy steeped in the purposes and methods of science using a content-laden and scientific inquiry approach. Although the endpoints of the two constructivist approaches differ, the first being a conceptual change toward a more scientific way of viewing the world and the second a more open-ended acceptance of an individual's beliefs about the world, Eisenhart et al. believe they both fail to locate learning in its societal and historical context. They suggest a need to broaden the notion of constructivism that will allow an analysis of the

> structural characteristics of schooling or science, the social organization of instruction, the tools of language and inquiry that motivate what teachers and students do in school and science, or the identities that school science inspires...they do not challenge the collective means of viewing and manipulating the world that preserve the status quo in schools or science" (p. 278).

This is because

> Nothing in Piagetian or radical constructivism suggests how constructivist-oriented teachers should handle controversies about "good" uses of science, how principles of "equality" learned in mathematics classes might be applied outside the classroom, how the social meaning of being a "Black man" might correspond with the social meaning of being a "scientist", or how males biases in scientific language and inquiry might be altered. (p. 279)

Eisenhart et al. suggest sociohistorical constructivism as a theory that will fulfill reformist goals toward a more socially responsible scientifically literate citizenry. This rendering of constructivism accepts and promotes the idea that individual learning, in addition to being actively constructed through adaptation, is "historically and culturally constituted". This means, in short, that what we learn, how we learn it, how it is taught to us, and why it is taught to us, is shaped by external forces that "make or produce the ways in which people think, feel, and act" (p. 279). Sociohistorical constructivism requires an "authentic" context through which to learn. This recognition comes from the work of Lave & Wenger (1991) and their focus on identity and motivation to learn as something that comes from within. Learning in such an environment is motivating to students because they can connect personally with the possibility of who they can be or what they can do as a result of their learning. Shamos (1995) would agree with this idea, he states that "students and adults will evidence a genuine interest in scientific literacy only when they are convinced that becoming literate in science is for their personal good, not simply because science educators or commission reports tell them so." (p. 97). Eisenhart et al, similar to Hurd (1997), are steering science education reform more pointedly in the direction of personally relevant experiences. Unlike both Shamos and Hurd, however, they draw on the work of feminists, social psychologists, and anthropologists to broaden the image of what "relevancy" can and should mean in science education. Additionally, they raise questions concerning not only the low expectations of the reform efforts to fully teach about the history, philosophy, and sociology of science but about the learning theory that prohibits full realization of the reformist goals for scientific literacy. Sociohistorical constructivism and Lave's theory of situated learning (1991) will reappear later in Section II of this paper where I will expand upon the ideas of culture, identity, and community as they relate to learning in the classroom, and female learning in particular.

Section Summary

In summary, the science education reform efforts enacted by AAAS, NSTA, and the NRC, though highly acclaimed and utilized, are not without critics. Because these efforts impact science education reform at the college level, an understanding of their goals and subsequent critiques is important for an informed discussion. As we have seen in this brief overview, many believe that the reform documents have not made radical enough changes in why and what they expect students to learn in and about science. In addition, Rodriguez (1997) asserts that the NRC's document may be ineffective as a result of its discourse. His analysis reports that the Standards fail to mention ethnic groups specifically and offer no compelling arguments to foster teacher change toward a more equitable pedagogy. Considering the relationship between the three major reform documents, his arguments can most likely be made against the other two as well. Though most critics are not necessarily questioning the language defining scientific literacy, we have seen that the idea of who specifically can be scientifically literate and how to achieve it differs amongst educational researchers, teachers, the general community, and the how the reform documents articulate the problem and its solutions.

Some agreement exists that the multitude of research on the nature of science and its importance to science education is being narrowly represented in the reform initiatives because of an over-emphasis on teaching the individual disciplines' scientific content and methods inquiry. Implementation efforts are lacking in regards to teaching educators how to effectively teach about the history, philosophy, and sociology of science. Understandably, teaching along these lines is difficult and the literature bears out that efforts to instruct teachers on the NOS have not always been successful (Felske et al., 2001). Critics of reform question how individuals can become socially responsible and make informed decisions about science in their lives without explicit coverage and action on these topics in science education. And, they are calling for a more contemporary and useful representation of the purposes and methods of science that make explicit the essential role of technology in our lives.

My personal definition of scientific literacy makes use of Scribner's (1986) metaphors presented earlier. Scientific literacy is first an attitude of involvement in science, this also may be considered as personal science agency and likened to Scribner's sense of literacy as power. Specifically, it applies to arenas in which a person has little formal knowledge or experience. It also focuses more on the application of scientific literacy in our everyday musings and puzzlement's and removes it solely from the need to make rational decisions on global pressing environmental and health related problems.

Personal science agency provides an individual with the desire and power to ask questions and a secured confidence that the questions are worthwhile and important. My idea however, goes beyond Scribner's definition of functional literacy as the proficiencies toward effective functioning in the world – and though I am not discounting that life necessitates a degree of functional literacy that includes acquiring a certain amount of knowledge and the development of thinking and manipulative skills, it focuses more on a goal related to the "enlarged understanding of ideas and values" that includes understanding the "contexts of personal matters, social challenges, historical perspectives and cultural perspectives" (Trowbridge, Bybee, Powell, 2000, p. 70). I propose that an attitude of involvement in science seeks to do more than just allow an individual to "function". It mandates involvement and can be applied to experiences as personal and mundane as trying to understand why birds won't come to a new birdfeeder, why one's child should or shouldn't be given fluoridated water in school, or why one's car continues to leak oil. It is includes Hurd's (1997) promotion of scientific literacy that calls for a "lived curricula" for education whereby students' lives, communities, and futures are accommodated in the science/technology curriculum. Further, it diminishes how often we defer fully to the experts for answers or just give up on perplexing questions.

Like Shamos (1995), I doubt everyone can know all the science needed to reason like experts on issues important to society and we need to cultivate "scientific habits of the mind" (from Dewey) – however, he expects too little of the average person with respect to cultivating a desire or motivation to know and understand the science that does confront us daily in our personal lives and occupations. He advocates too much deferment and too little personal science agency. And unlike Eisenhart et al., he fails to address the sociohistorical/cultural biases and norms that pervade scientific reasoning and explanations. This brings me to the next part of my definition of scientific literacy that relate to Scribner's personally favorable potential of being literate and how it affords an individual special attributes. A scientifically literate person ought to understand that, for example, Shamos' experts *are* afforded "special attributes" in our society and in fact others will defer to them. My definition of scientific literacy includes an awareness and understanding of the sociocultural mechanisms that have constructed an "awe" around experts and can, at times, cause them (whether they are doctors, mechanics, or the ornithology-minded woman who works at the birding store) to fail to afford legitimacy to the questions posed by laypersons. Here we see the need for the scientifically literate person to remain empowered and not allow her desire to learn or confidence about the legitimacy of her questions to be thwarted.

I believe that Eisenhart et al. offer an important yet neglected theoretical learning theory, *sociohistorical constructivism* as a way to reconceptualize what happens in the classroom as teachers teach and students learn science. The data I have analyzed from pilot studies relating to how females experience science in a reformed college level classroom (Weiss, 2001) corroborate that identity and external forces shaping experience have an impact on what and how students learn. Identity and external forces also play a role in achieving personal science agency as described above.

With respect to college classrooms however, I am unsure how much further professors are willing to venture into the more affective domains of their pedagogy to promote the definition of scientific literacy described above. Hopefully, my research will elucidate the need for educators to teach beyond the purposes and methods of science and challenges them to personally reflect on their position within the scientific community of practice and issues of dominance and exclusion. My definition o f scientific literacy begins to explore how the disregarded domains of the nature of science affect individuals' beliefs about how they can/should interact with science and scientific thinking in their lives.

To further this elucidate this idea, Section II considers marginalized groups and the role of identity in science and science education.

Section II: Marginalized Groups, Culture, Community, and Science Education

> "When I started out, I felt all the time like an amateur." (Mildred Dresselhaus, member of the National Academy of Sciences and MIT professor)

> Ms. Dresselhaus remembers wondering, "Why me?", when she was hired as an MIT professor. (Schiebinger, 1999, p.59)

> I resigned my position as a full, tenured professor because I was tired of being treated as less than an equal person. I was tired of being condescendingly called 'Hon' by my peers, of having my honest differences of opinion put down as a manifestation of premenstrual syndrome, of having my ideas resigned because of a subtle sexism that, while not physically harmful, is extremely pervasive and debilitating. (Dr. Frances Conley, a top neurosurgeon, Stanford University's Medical Center in Schiebinger, 1999, p.52)

> After twenty-four years of service to the university, Dr. Conley "described an environment where, as late as 1991, faculty members spiced up lectures with slides of Playboy centerfolds, where sexist comments were frequent, where those who were offended were told to be less sensitive, and where unsolicited touching and fondling occurred between male house staff and female students. At age fifty, Conley said, she no longer wished to work in a "hostile" environment" (Schiebinger, 1999 p. 52).

Introduction

As we have seen in Section I, the goal of scientific literacy can be conceptualized in many ways that affects its implementation in science classrooms. In this paper, Eisenhart, Finkel, & Marion (1996) introduce us to the notions that 1) current initiatives may be unable to realize their goals because of the omission of a sociological and historical perspective guiding what it means to be scientifically literate and how people learn, 2) we need to be critical of the underlying premises upon which reformed learning theory exists, and 3) sociohistorical constructivism offers us a pedagogical mindset through which to engage students' identity and its development in the process of learning science and becoming socially responsible users of scientific knowledge. I posit that reform efforts need to reconceptualize their traditional epistemological commitments and theories of how students learn (Brickhouse, 2001; Eisenhart, Finkel, & Marion, 1996). Additionally, such efforts need to focus on not only what a student learns and does in class but why. This requires an adherence to the range of identities students bring with them into the classroom and the possibility of transforming student identity (Brickhouse, Lowery, & Schultz, 2000; Brickhouse, 2001; Wenger, 1998). However, reform initiatives, realized through higher education projects like STEMTEC, rarely expect participants to conceive of science education in this way.

Science education at the college level, considered a large section of the science pipeline, often times implements reform using a formula of prescribed teaching strategies and constructivist learning theories that, mixed together, equal change. The reform-minded professor attends workshops, seminars, and discussions to learn more about pedagogy and course revision. Course revision itself is very is action-oriented and tangible -- course scheduling, teaching strategies, classroom activities, test-taking procedures, and student assessment is changed while content is introduced in new ways. Revision efforts are documented and evaluated to determine if students are getting higher grades, enjoying the course in general, and showing an interest in the topic. Yet, when considering learning from the perspective of Eisenhart et al., one must ask, in what ways have these efforts impacted student identity? Is passing the general education science course still just an academic "hoop"? Has her experience in a reformed course brought about meaningful science learning?

Questioning the process and outcomes of science course reform is similar to feminist critiques of reductionist thinking about the nature/nurture dichotomy in scientific research. Rosser (1990) describes the latter critique as one that repudiates the implicit assumption of biological determinism. Biological determinism assumes "that biology (genes) determine behavior and that biological effects may be measured separately from those of culture" (p. 26). Organisms, therefore, can be isolated and studied devoid of explicit research into the interdependence of organism and environment. I suggest that science education reform mimics biological determinism by conceiving of the learner in the classroom as an isolated organism. Reform that promotes a multitude of pedagogical strategies grounded only in Piagetian and radical constructivism ignores the interdependence of learner and environment (O'Loughlin, 1992). I use the term "environment" here from a sociocultural perspective, as a socially constructed point in space and time that is acted *upon by and acts on the student*. I conceive of the learning environment as a place awash in the radiating ripples of communities (Wenger, 1998). As we shall see, advocates of situated learning theory (Lave, 1992; Wenger, 1998; Brickhouse, 2001) place major emphasis on the environment or "situation" and identity as a way to understand the teacher, learner and effective instruction. Situated learning theory, as I argue later in the section, offers students opportunities for meaningful learning. Whereas conceiving of the students' actions as the product of her biological determinants not only is inaccurate, it has disturbing links to the "biology as destiny" thinkers of the past.

The notion of meaningful science learning is very broad and multidimensional. I will briefly describe my ideas and understandings about the idea in the context of females' experience learning science. First, meaningful learning requires that content learning outcomes expected by the teacher are relevant to students' personal and future lives. This calls for explicit direct connections to females' daily lives, scientific encounters, and intended livelihoods. Additionally, it is necessary for students in a course to critically examine the history, philosophy and sociology of the science discipline in order to reflect on personally consequential issues such as how the discipline proceeds, who decides its progression, and related implications and outcomes. These conditions should be met as students confront personal and group beliefs about science. These conditions offer a pathway toward science education that is transformative [citations here]. Getting at females' biases and assumptions about who can/should do science is key to this scenario. Understanding female behavior in the context of the learning setting and its dependence on not simply how they are being instructed, but also the range of student/professor beliefs and university/societal learning outcomes will further highlight that which promotes or impedes meaningful learning.

In this section of the paper, I explore and define the issues surrounding the phenomena of female exclusion from the sciences. Explorations inform the overall discussion by highlighting 1) aspects of the history and nature of science that have worked to exclude females and men of color, 2) how culture, through the development of our identity, mediates what females can know and learn in science as well as what is possible, acceptable, and right in society, and 3) how a social justice perspective unpacks the hegemonic nature of science, and 4) introduces situated learning theory and sociohistorical constructivism as means to making the above explicit and transforming the teaching and learning of science. I begin by summarizing important aspects of feminist theory about science to set the scene for my assumptions about female identity and how it influences learning in the science classroom.

Feminist Perspectives

> Until very recently, very little contact occurred between the feminist and scientific communities. A handful of scientists has worked in women's studies since the beginning of the second wave of feminism in the late 1960s, developing feminist critiques of science, pointing out gender bias in basic and clinical research, and evolving curricular and pedagogical techniques to attract and retain women in science. The mainstream community of scientists has remained unaware or, in some cases, has actively ignored or challenged this feminist scholarship produced by their scientific colleagues. (Rosser, 1997, p. 81)

A literature search using key words such as feminist theory and science, gender and science, and females and science, to name a few, returns the titles of hundreds of books and journal articles theorizing and postulating on the present and historical nature of the scientific endeavor and how it has systematically excluded, for a variety of reasons, females and men of color. Offering a few book titles will better illustrate the extensive range of literature in this field; Uneasy Careers and Intimate Lives: Women in Science (Abir-Am, Pnina, Outram, 1987), A Matter of Choices: Memoirs of a Female Physicist (Ajzenber-Selove, 1994), Women, Feminism, and Biology: The Feminist Challenge (Birke, 1986), The Equity Equation: Fostering the Advancement of Women in Science, Mathematics, and Engineering (Davis, Ginorio, Hollenshead, Lazarus, &

Rayman, 1996), Sex Differences in Cognitive Abilities (Halpern, 1992), Whose Science? Whose Knowledge? Thinking from Women's Lives (Harding, 1991), Nobel Prize Women in Science: Their Lives, Struggles, and Momentous Discoveries (McGrayne, 1993), Love , Power, and Knowledge: Towards a Feminist Epistemology for the Natural Sciences (Rose, 1994), Has Feminism Changed Science (Schiebinger, 1999), and Toward a Laboratory of One's Own: Lesbians in Science (Hynes, in Lesbian Studies: Present and Future, Cruikshank (Ed.), 1982). Within these texts are the voices of feminists positioning themselves differently as they come to describe and understand "femaleness" in a world where masculine is normative. Rosser (1997) states that "...all feminist theory posits gender as a significant characteristic that interacts with other characteristics, such as race and class, to structure relationships between individuals, within groups, and within society as a whole" (p. 82). She concisely summarizes the various perspectives of feminists (footnote) including liberal, socialist, African American/womanist, essentialist, existential, psychoanalytic, radical, and postmodern. Based on her writings, I would position my feminist position for this paper in four of these stances; socialist, existentialist, and psychoanalytic because of my sociocultural perspective that accepts culture and identity as social constructions that operate to exclude females from science and retain, in general, their lower socioeconomic status, and postmodern because of its critical standpoint.

Historical Interpretations of Science, Gendering Science, & Who' s In

Science is an enterprise steeped in hegemonic practice that has excluded females and people of color since at least the Enlightenment (Brickhouse, 2001; Keller, 1985; Schiebinger, 1999). This followed the proclamation that "all men are by nature equal". Schiebinger (1999) nicely describes the historical significance of this announcement and, unless otherwise noted, the following discussion reflects her work.

Science became "gendered" in the late 18th century, as European society was being rebuilt following a period of political unrest and revolution. This rebuilding , in effect, promoted the divulgence of the spheres of public life (government and professionalism) and private life (hearth and home). The result was to remove females from public life (in government and the professions, such as science) under the conveniently popularized theory of *sexual* *complementarity*. This theory purported that women are men's complementary opposite, meaning that women were not inferior to men but were "fundamentally different". This idea "fit neatly into dominant strands of liberal democratic thought, making inequalities seem natural while satisfying the need of European society for a continued sexual division of labor" (p. 71). Thus, equality need not be an issue, the concern was irrelevant.

The impact of the theory, supported by known philosophers such as Georg Hegel, caused society to philosophically conceive of women as physically, intellectually, and morally in opposition to the "public rational man". The science professions, as they became increasingly formalized embraced the theory. It helped to explain what was and was not scientific *scientifically*. Women were understood to be physically "incapable of discerning the abstract and universal", they "lacked genius", and "a certain strength of mind and body" (p. 71). Immediacy, practicality, subjectivity, and feeling were not characteristics of science, they were characteristics of women, and therefore women could not be scientific. Here we see the advent of the objectivity/subjectivity, mind/body, and masculine/feminine dualisms that continue to plague efforts to achieve equality in the sciences and society as a whole. We also see the deep roots of the expectation that a "women's place is in the home" as a result of an historical interpretation of biological needs and abilities that offered (and still offers) men a rationalization for gender inequalities. It is also incredibly important to report that the constructs about female and male "places" in society were assigned only to middle class Europeans. People of color were by design inferior. Positive traits of masculinity and femininity were believed unique and ordained to the dominant in society. These beliefs allowed science to be defined, described, and progress as an irrevocably masculine domain Keller (1982, 1985). In the late 1800s, Francis Galton, British explorer, anthropologist, and eugenicist, described men of science as "strongly anti-feminine; their mind is directed to facts and abstract theories, and not to persons or human interests… they have little sympathy with female ways of thought" (Schiebinger, 1999, p. 71).

As science formally progressed into more formal disciplines beginning in the late 1800s, constructs appeared that determined and delineated their purposes and methods. Within these domains, science was professed to be elegantly objective and value free and would continue this way because of the innate symbiosis between masculinity and objectivity. Georg Simmel, a sociologist, bears out this belief in his 1911 statement below. Here we see the common sense notion, clearly proclaimed since at least the writings of Bacon in the 1600s (Keller, 1985), that judgements must and can be objective, and the only perspective to achieve this is masculine.

> The requirements of correctness in practical judgments and objectivity in theoretical knowledge... belong as it were in their form and their claims to humanity in general, but in their actual historical configuration they are masculine throughout. Supposing that we describe these things, viewed as absolute ideas, by the single word "objective", we find that in the history of our race the equation objective = masculine is a valid one. (Schiebinger, 1999, p. 65)

The accommodation of these beliefs into our culture has had practical realization in the activities of family, schools, scientific communities, and society in general. Harding (1991) further elucidates this effect:

For one thing, the very same personality traits that young males must take on to become masculine in the modern West are just those that are particularly valued for careers in science and related fields. Facility in abstract thought, physical interaction with the environment, and a conception of nature as separate and in need of control – which parents and the society encourage in male children in order to make them more manly – are just what prepares young people to like and excel at math, science, and engineering. Correlatively, in order to make female children feminine and womanly, parents encourage a tendency toward concrete and rational thought and a preference for personal, caring service to other people. These traits prepare girls and women to prefer teaching, mothering, and other service and caring activities to those that are essential for careers in mathematics, science, and engineering. (p. 28).

In this way, culture colluded with stereotypes to structure obstacles to female participation in science. This was important because science doctrine has had to resist the feminizing of its disciplines and subsequent lowering of its status (Delamont, 1989). And, although history documents the gains women achieved in science through entrance into elite educational institutions beginning in the 1870s (Sadker & Sadker, 1994), the full realization of successful female careers in science is still uncommon. "The National Science Foundation has found... that after correcting for age, experience, and education, discrimination remains the only explanation for women's and minorities poor positions and salaries" (Schiebinger, 1999, p. 37). And of those women who do achieve in science professions, many express uneasiness about their ability and/or how colleagues treat them. The devaluing of women's work, both within and outside of science (Harding, 1991), likely bolsters these feelings.

It is obvious by my framing of the argument that I concur that science is gendered. Of course, there are scholars who strongly refute that claim (Bloom, 1987 in Rosser, 1997). They fail to see how, for example, the study of mineralogy or the moments following the big bang are questions with a masculine slant. While we can readily point to gender bias in some fields, for example, in medical research the historical use of males only or the lack of knowledge of early AIDS symptoms in females until the mid-1990s (Bianchini et al., 1999), the substance of research in some scientific disciplines does not so easily lend itself to feminist critiques. However, raising again the five critical domains of the nature of science, we see that a discipline is not simply its facts, theories, or laws, but a multidimensional entity consisting of socially driven purposes, methods, philosophies, history, and strategic intents. How then can we ignore the "whom" in the choices made in all fields of scientific research and application? Who is the tenured professor researching minerals from pegmatites in Africa or powering up the electron positron collider in Switzerland? Who is on the research team? What other questions might the team have asked? What are the societal implications of their work? Yes, it is a masculine enterprise, as noted by who populates its community, how it is practiced (the choice of experiment topics, methods, interpretations as well as the promoted theories and their applications), and its professed knowledge (Delamont, 1989; Haraway, 1988; Keller, 1985; Rosser, 1990).

As I consider how this phenomenon plays out in the college classroom with non-science majors, I am struck by its earlier effects on the various populations of females. Females, throughout their pre-college years, learn not just science content but also if science is "for" them. More often than not, with math serving as a critical filter (Schiebinger, 1999), they choose to pursue careers outside science (NSF, 2000a). Yet, in some areas of science and mathematics education and careers, females are improving their participation.

Substantial gains have been made in the participation of women, minorities, and persons with disabilities in science and engineering in the last two decades. The gender gap in high school mathematics course taking has disappeared for the most part, and women are earning close to half of the bachelor's degrees in science and engineering. The employment experiences of women, minorities, and persons with disabilities in science and engineering are also improving. Unemployment rates no longer differ by sex, although differences remain among racial/ethnic groups and between those with and without disabilities. Salaries, controlling for field and length of experience, are similar across sex, race/ethnicity, and disability categories and the proportions of scientists and engineers in management within certain age categories are similar across sex, racial/ethnic, and disability categories. Despite similarities, widely different levels of participation exist within fields, degree levels, and sectors of employment. (NSF, 2000b, p. 1)

Gains are being made, however "widely different levels of participation" still exist. Why? Students in science courses bring the conscious and internalized effects of the conventional nature of the scientific community into the learning setting. These psychological and sociological effects guide students' conceptions of science and ultimately what they value and believe is possible, acceptable, and necessary with respect to learning and doing science. Certain "school characteristics" (NSF, 2000b) play into these conceptions, including tracking, judgements about ability, number and quality of science and mathematics courses offered, access to qualified teachers, access to resources, curricular emphases, access to teachers and services that reduce language barriers, the existence of role models, and inclusion practices for students with disabilities (Oakes, 1990; Weiss, Matti, & Smith, 1994). The NSF document, Women, Minorities, and Persons with Disabilities in Science and Engineering (1998) present the educational outcome of these factors -- that is students being put at risk for success and interest in math and science.

A Social Justice Perspective: The Role of Culture and Identity in Science & Science Education

Culture

In order for me, as the researcher, to make sense of students' science conceptions and describe the potential for meaningful learning, I need to understand the multitude of factors impacting those conceptions. More specifically, I must consider the role that culture plays in shaping identity.

Webster defines culture as "the totality of socially transmitted behavior patterns, arts, beliefs, institutions, and all other products of human work and thought typical of a population or community at a given time." Culture determines norms and expectations. Bullivant (1988, p. 24) writes, "Culture embodies strategies by which social groups maximize their perceived advantage relative to other groups, it not only contains survival instruction but also often an elaborate justification for their type and purpose." Schwartz (1996,p. 9) sees it comprised of the "beliefs, behaviors, and artifacts of a group of individuals that recognizes itself as a unique community." Our culture is a fabric woven with threads of injustice that determine not only who can be CEO of Ford, but also how a young female college student conceives of herself within the scientific community. Is there a place for her? Does she want that place?

Culture operates to maintain and justify females' sense that they should not connect too closely with the community of science. Because formal science is generally experienced through schooling, our educational system, the product of cultural and societal norms, maintains this sense. One predominate way this is enacted is through the discourse in science education that privileges certain genres of communication, i.e. how language and written expression is used (Hildebrand, 1998). Another way is by encoding science within a system of rationalization that objectify nature and society, thus providing those who can think rationally power over others (Kumashiro, 2001). Additionally, the culture of science has "rituals of day-to-day conformity, codes of governing language, styles of interactions, modes of dress, [and] hierarchies of values and practices" (Schiebinger, 1999, p. 67) that manifest themselves in the classroom and promote the image of science embodied by the Western white male.

I believe reform efforts in science education are generally initiated devoid of explicit considerations of how cultural oppression operates within science, the educational institution, the reform effort, and female identity. I also realize that the applying the term "oppression" to the actions taken by well-meaning adults will be resisted by some. Kumashiro (2001), however, suggests that oppression in the classroom exists as a result of our resistance to change how we see our place and ourselves in the world. It exists as a result of

> ... our sense that what we have come to believe is normal or commonsense in society is really the way things are and are supposed to be. After all, imagine the alternative: Imagine constantly learning that "what is normal" and "who we are" are really social constructs maintained only through...the marginalization, the silencing of other possible worlds and selves. Imagine constantly learning, in other words, of our own complicity with oppression. (p. 5)

Yet, science education reformers share with social justice educators a goal of inclusion and equity for all. Social justice educators, however, realize the necessity of understanding individuals and their history within the context of change. They realize that in order for students or teachers to understand oppression in society, they must understand their participation in culturally prescribed dominant and targeted groups. In order for females to understand the relevancy and role of science in their lives, they must comprehend their cultural exclusion from the scientific community. This includes a realization that they are both victims of and at times unknowing contributors to that exclusion. Social justice education offers the theory and implications of consciousness-raising realizations of this type that can demystify science and offer females informed choices about its role in their futures. In addition, it offers teachers desiring to change their practice a lens through which to better understand the personal and cultural constraints to change.

In this next section of my paper, I summarize the issues and theories of social justice and multicultural education. Interspersed into these summaries are reflections of how these ideas bear on my research interests. This section of my paper is personal and reflective as I take steps toward understanding the incipient nature of oppression within the science community, institutions, and a college classroom and its impact on identity.

Social Justice Education

Adams, Bell, and Griffin, in their book, Teaching for Diversity and Social Justice (1997), believe that social injustice exists explicitly and implicitly within the fabric of our society. They call for ending injustice by making it known and transforming it. They offer a means to that end through social justice education that they define as "a process and a goal" for " full and equal participation of all groups in a society that is mutually shaped to meet their needs" (p. 1). They believe social justice is key to balancing the unequal distribution of resources and opportunity. They hope for a society in which everyone feels "physically and psychologically safe and secure" (p.1). Social injustice education is described through the term oppression.

Oppression

Oppression, is the term chosen by Adams et al. to characterize the "pervasive nature of social inequality" inherent in our academic institutions and society as a whole. They further define oppression as; 1) restricting because of the "structural and material constraints" that act on a person's possibilities for the future, 2) hierarchical as a result of the privileged relationship whites have over people of color, and males have over females that awards members of the majority power, status, and economic gain at the cost of minority, 3) a complex mix of multiple, cross cutting relationships (i.e., a man of color attains a level of power and economic status through his career yet is still subject to society's discrimination and bigotry), and 4) an internalized psychological phenomenon residing in both benefactors and victims alike which offers a bizarre rationality to the existing inequality (i.e. "the idea that poor people somehow deserve and are responsible for poverty... is learned by poor and affluent alike" , p. 5). Oppression, then, is Adams et al. term that can help to frame my thinking about the experience of underrepresented groups in a reformed introductory level college science course. It promotes conceptual questions (See Table 1 in Appendix A) such as; Why is this person here, by what means did they get here and will they go from here? At what cost are they here? What type of oppression does this individual experience on a daily basis in this classroom, by those around her/him, at this institution, in this town? How does this person understand her/his oppression and it origins? How do beliefs impact expectations of success or failure in a science course or career or achieving a general sense of scientific literacy?

Oppression and Group Membership

Adams et al. stress that oppression "cannot be understood in individual terms alone, for people are privileged or oppressed on the basis of social group status" (p. 9). They describe how the accomplishments or failures of people in dominant groups are attributed to them as individuals while people in subordinated groups are more likely to succeed or fail in light of their social group. For example, a successful black female in science is considered exceptional and a rarity while a black female doing poorly in science is seen as portraying the limits of her social group. Because group membership is not always obvious it is incredibly complex. Group membership can vary in degree, can be overt or covert, individually or socially chosen, and correctly assumed or grossly misapplied. What are the various group memberships of my research participants? How do those memberships act on teaching and learning in science?

Hegemony

How one identifies herself and her social group is directly related to hegemonic structures within our world. Hegemony acts at the societal, institutional, and personal level. Adams et al. define hegemony (p. 11), through many authors, as 1) an explanation of "the way in which power is maintained not only through coercion but also through the voluntary consent of those dominated", 2) the way in which "a dominant group can project its particular way of seeing social reality so successfully that its view is accepted as common sense even by those who are in fact disempowered by it", and 3) a way to "understand power as relational and dynamic... rather than as something imposed from top down". Further, they summarize that power inequalities exist not merely as a result of persons or groups actively imposing their will on others, but also when "well-intentioned" people unknowingly act as agents of oppression by simply living their lives ignorant of oppressive agents. This can occur when, for example, able-bodied persons access buildings unaware of inaccessibility to building by physically challenged individuals. Discourse practices (ideas, texts, theories, language) used and accepted by the dominant culture maintain hegemony. Students in a university science course are engulfed by hegemonic practice as are professors working within an institution that decides whether or not they deserve tenure.

The "isms"

Adams et al. offer a framework through which to understand these issues by "identifying ... the particular characteristics of specific forms of oppression" and how it is "manifested through racism, sexism, classism, anti-Semitism, ableism, and heterosexism" (p. 5). Their writing includes an historical perspective on the "isms" and how they are interconnected under an overarching presence of domination(See Table 2 in Appedix A). Applying their definitions to the pervasive nature of oppression categories listed earlier leads me to ponder the influences of the "isms" in the college science classroom. More specifically, how do the "isms" restrict possible access and opportunities for relevancy in this setting and what hierarchies exist that impact how a student thinks, behaves, talks, and who they interact with? With respect to those acting in the setting, how do they mediate experience with multiple forms of oppression and how does experience impact class performance and interest? Finally, what simple dualisms exist in the minds of professors and students regarding who can/should learn science?

Considerations of oppression and how it is manifested and maintained necessitates exploration into its development interaction within one's social identity. The effects of oppression manifest themselves in our social identities.

Social Identity

Hardiman & Jackson (1997, in Adams et al.) present a conceptual "generic" model of social identity development. The intention of the model is to offer a way to examine "how members of agent and target groups experience internalized domination or internalized subordination and change their sense of relationship to other members of their target or agent group at various stages of consciousness" (p. 17). Their definition of social oppression relies heavily on the idea of collusion, in which agent groups "take control over time of a society, as well as the minds, ideology, language, culture, and history of the targets" (p. 17). They offer a social oppression matrix to show how social oppression operates at three levels; the individual, institutional, and societal/cultural (See Table 3 in Appendix A). These three levels work and interact through three dimensions; the context, the psychosocial, and the application. For example, the context dimension is comprised of an individuals beliefs, actions, and attitudes. The context of institutions (family, government, industry, education, religion) shape individuals in society and produce oppressive consequences, such as unequal treatment of blacks and the poor in the justice system. Context maintains societal/cultural oppression by normalizing the values that bind individual and institutions that guide, for example, our philosophies of life, good, or normal. Psycho-social processes are the conscious (knowingly supporting oppression) and/or unconscious (unknowing or naively maintaining oppression) type of collusion involvement of the context levels. Application is the manifestation of oppression through attitudes and behaviors such as stereotypes that women can't make it in business or an individual harassing a gay man. It is within this matrix that the participants in my study reside. The community of science is, to a degree, embedded in the societal realm of social injustice. Additionally, science education inequalities are embedded in the institutional inequalities of the university.

The authors also present a social identity development theory that "can be helpful in understanding [individuals'] perspectives" (p. 23) (See Table 4 in Appendix A). Individuals may be in either agent (dominant) or target (minority) groups based on the context of the setting and therefore develop unique social identities. They propose that individuals develop a social identity by passing through the stages of naïve/no social consciousness (birth to early childhood), acceptance (internalization of the dominant culture's systems of belief), resistance (question dominant roles in society), redefinition (of self in social group), and internalization (extend the consciousness of one's new social identity into the unconscious attitudes and behaviors of everyday life).

The authors' generic social identity model proceeds in stages that do not, in real life, proceed through such definitional constraints. They believe that individuals may experience different stages in relation to different issues and forms of oppression. This model points out the depth and variety of oppressed/oppressor roles that students and professors experience. More specifically, the model offers a context for understanding how experiences in science, math, learning institutions and society shape identity and embedded beliefs about the future. It offers a perspective through which to reflect on teachers and learners actions in the science classroom.

Pedagogical Frameworks

Adams et al. stress that when designing instruction that aims to be transformative, connection must be made to social and cognitive models of identity development. Connecting the two offers a pedagogical perspective through which to answer questions like, "Who is the learner? What are her/his processes of understanding and meaning making? What are the effects of classroom contexts or of groups and interpersonal dynamics (p. 39)?" More specifically, social development theories identify the dominant and target identities that are negatively impacted by societal structures privileging Whites, heterosexuals, Christians, or males. Social identity development theories offer a lens for seeing how others experience the world. Cognitive development theory aids in understanding what an individual can believe or value. Theories of college students' cognitive development indicate that college is a time of major cognitive changes; the ability to think in complex abstract ways increases as internal agency is favored over acceptance of external authority, a clear-cut mindset yields to an acceptance of doubt, and a proclivity toward independent inquiry deepens. As students move further along in their cognitive development they are often better able to understand and potentially transform aspects of their social identity and their world. This supports my assertion that female experience in the general education introductory level science course has the potential to transform how she conceives of the relevancy of science in her everyday and future life.

Below I briefly annotate the major elements of social justice education practice proposed by the authors. These elements are important to disclose here as they reappear in Section III in my discussion on inclusive pedagogy. They are student-centered and critical. Adams et al. have synthesized social justice practice into five principles (pp.42-43):

1) Balance the emotional and cognitive components of the learning process: teaching that pays attention to personal safety, classroom norms, and guidelines for group behavior.
2) Acknowledge and support the personal (and individual student's experience) while illuminating the systemic (the interactions among social groups): teaching that calls attention to the here-and-now of the classroom setting and grounds the systemic or abstract in an accumulation of concrete, real-life examples.
3) Attend to social relations within the classroom: teaching that helps students name behaviors that emerge in group dynamics, understand group process, and improve interpersonal communications, without blaming or judging each other.

4) Utilize reflection and experience as tools for student-centered learning: teaching that begins form the student's worldview and experience as the starting point for dialogue or problem posing.
5) Value awareness, personal growth, and change as outcomes of the learning process: teaching that balances different learning styles and is explicitly organized around goals of social awareness, knowledge, an social action, although proportions of these three goals change in relation to student interest and readiness.

These principles offer guidance for curriculum reform in the college sciences. They suggest incorporating attention to the learning environment, supporting the personal, attending to social relations, increasing reflection, and valuing awareness and personal growth into pedagogy. Pedagogical incorporation of these ideas fosters the connection between personal understanding/beliefs and public learning. It is rare to see such connections explicitly made at the college level, yet most science professors ultimately want learning to be personal for students. For example, a professor of geology recounted that he wanted students to "understand how the Earth works, the big picture" and to make informed decisions about the Earth's resources. A professor in another study stated:

> One thing I try to do is to show them that they actually know a lot of science and that it is as much a part of life as any other area. It always bothered me that people would more or less brag about their ignorance of science when they would be embarrassed to say the same thing about art or literature. Some basic knowledge of science is part of being an educated person. But many people have become intimidated and close their minds to it. I try to reopen them and help them see it every time they go to the grocery store or out for a walk.

Situated Learning and Communities of Practice

Situated learning is a general theory of cognition. It has mostly been used in problem-based technology education because of the authentic nature of those settings for learning. The theory recognizes and asserts that learning is, as Jean Lave states, a "social anthropology" of complex social activity. Lave (1988) is slated as giving contemporary understanding to this notion relying heavily on the social learning theory of Vygotsky (among others).

Lave argues that most learning environments promote abstract learning that produces non-contextual knowledge. Learning of this type is ubiquitous and dissociated from its setting.

Nor is it the natural way that knowledge is acquired. Instead, cognition occurs through the complex inter-relatedness of "mind, body, activity and culturally organized settings" (1988, p. 1) – it is a "socially situated activity" (p. 43). Additionally, such interactions are not just the effects of setting, they are co-constitutive of the setting.

Lave & Wenger's (1991) model of communities of practice adds an important principle to situated learning, namely, that novices interact with experts to move deeper into a community of practice. Unintentionally they come to know and model the culture of the community of practice and may move from its margins as a novice, to its center as an expert. Lave & Wenger (1991) term this process "legitimate peripheral participation." However, "community social structures, their power relations, and requirements for legitimacy define what is possible for learning, identity development, and participation." (Davis, 2001). Not being a member of the dominant group can greatly restricts one's access to insider status within a community of practice. Davis (2001) summarizes the gatekeepers to legitimate participation as 1) not having the necessary social capital, 2) not thinking or reasoning as the dominant group, and 3) having limited or negligible power within the community. She emphasizes Lave & Wenger's (1991) assertion that the more important aspect of the relationship between novices and experts, or masters and apprentices in a community, is one that confers legitimacy over one that provides teaching. This is a very salient point for my research interests. It speaks to the social justice issue of who gets "legitimatized" and how important it is in order to be and feel successful within a setting or community. Additionally, a fair characterization of the relationship between non-science majors in a science course and their professor is more often one operating from a deficit model in which the professor tries to bring students "up to speed" on requisite knowledge – forget the conferring of legitimacy.

Situated learning theory has been further developed by Brown, Collins, & Duguid (1989) by linking it with cognitive apprenticeship. An apprenticeship model advocates authentic learning environments that afford opportunities for practice. Their position has meaning to my work as it provides a model for thinking about the culture and operating mechanisms within a community of practice, such as science or a learning environment.

Brown, Collins, & Duguid (1989) offer a metaphor for understanding the perspective of learning proposed by the theory of situated learning. Because knowledge acquisition is a situated process developed through an activity, they liken knowledge to tools. "Tools", they write (p. 53), "share several significant features with knowledge: they can only be fully understood through use, and using them entails both changing the user's view of the world and adopting the belief system of the culture in which they are used". They describe further how individuals can own tools and even know why they exist but be unable to use them appropriately. On the other hand, people who use tools actively develop a deep understanding of the tool and its use in the world, and this understanding evolves as usage continues. Tool usage is defined by the community using it and is not the same for all communities. As learners develop from novice to expert they come to understand and interact with the tools (knowledge) in ways that are appropriate to their community. Brown et al. state that "Learning and acting are interestingly indistinct. Learning being a continuous life-long process resulting from acting in situations"(p. 54).

However, Brown et al., lament the process of learning most often used in classroom settings whereby knowledge is acquired devoid of its cultural context. They call for allowing students to enter a community of practice as an apprentice and become enculturated into the culture. In this way, students can observe community members and practice appropriate language, questioning styles, and behavior. Immersion into the culture that embodies the subject to be learned offers students a pathway to knowledge acquisition that is more in line with how they have learned to be in the world. It also offers a different community of practice, other than the culture of school life, for students to aspire to or model themselves after.

At this point it is important to return to the ideas around Lave & Wenger's (1991; Davis, 2001) explanations of the pathways and gatekeepers to a community of practice. Davis (2001) writes, "a hierarchy of membership may result in newcomers and/or those marginalized within the group having little decision-making power about their experiences, the values, ways, and practices of the group, and the recruitment and inclusion of new members" (p. 371). If we consider female non-science majors in a science course as Davis' "newcomers", and accept that they have been, to varying degrees marginalized by the community of practice, then we can describe the injustices they face as a result of their powerlessness. This returns us to my earlier discussion on scientific literacy. Hurd (1997), leaving out issues of bias and discrimination in science, asserts that

> Science/technology in personal and civic contexts requires special ways of thinking, recognized as higher order thinking skills. To achieve this goal requires that students be able to distinguish evidence from propaganda, probability from certainty, relevant questions from pseudoquestions, rational beliefs from superstitions, data from assertions, science from myth and folklore, credibility form incredibility, sense from nonsense, fact from fiction, and theory from dogma. Higher order thinking skills are related to the optimal use of science knowledge in personal and social contexts. (p.17)
>
> ...when science/technology information is brought into contexts where it serves people and society, elements of ethics, values, morals, bias, prejudice, politics, judiciary, ideals, tradeoffs, and probability become a part of the thinking process. (p.17)

From a critical perspective, and agreeing with Hurd's notion of what higher order thinking entails and why it is necessary, we can come to understand the injustice and harm caused by allowing gatekeepers to legitimate scientific participation stay in place. I am not advocating here that every female should become a scientist, instead I am thinking in much more practical terms. In terms of how science and technology are so embedded in what we accept about and how we construct our lives. A few examples will hopefully illustrate my point. Green lawns need pesticides. Town water may have high nitrate levels. Buy bottled water. New rugs outgas synthetic chemical gases. Vaccinate your children. Take vitamins. Try Echinacea when you have a cold. Use sunscreen. Our bodies need sunlight to synthesize vitamin D. Buy organic. I could go on and on, but the point is that by keeping the majority of females on the margins of the science they remain powerless to make decisions and be critical about the science that affects their everyday lives, not to mention their occupations. Of course, this is the argument that advocates of scientific literacy have made for years, and yet, the reform efforts being proposed to ameliorate the "problem" of scientific illiteracy are failing to critically examine the underlying epistemological, philosophical, and structural dimensions maintaining it.

<u>Section Summary</u>

From the standpoint of social justice education, situated learning, and how communities operate, we see that traditional practice within science and science education effectively maintains gatekeepers to participation for those individuals and groups who do not have the necessary social capital and represent community norms. Specific to the case of females and science, the scientific community and its subgroup of science education, promotes gender neutral practices while in fact it is "gender blind" (American Association of University Women, 1992; Davis, 1999).

Traditional pedagogy, because of its epistemological commitment to learning theories purporting that students construct knowledge individually (O'Loughlin, 1992), and its enactment through "the precise, well-defined problems, formal definitions, and symbol manipulation of much school activity" (Brown et al, 1988, p. 57) acts as such a gatekeeper (Rosser, 1990, 1997; Schiebinger, 1999; Bianchini et al., 1999). Situated learning theorists postulate that a new epistemology for learning that incorporates the "the general strategies for intuitive reasoning, resolving issues, and negotiating meaning that people develop through everyday activity" " (Brown et al, 1988, p. 57) is needed. In Section III, I consider the literature on teacher thinking and change to understand the critical factors influencing teachers' predisposition for traditional pedagogy. I then offer inclusive pedagogy as a way to situate female learning in authenticity that acknowledges the hegemonic nature of science and empowers females to move from the margins toward a personally meaningful participation the scientific community of practice.

Section III: Teacher Change and the Transformation of Science Education

> Change begins when people decide to do things differently. Each change spreads in unpredictable ways, leading to other changes. (Lemke, 1990, p. 167)

This section presents proposals for the transformation of science education toward a reformed inclusive enterprise. Drawing on a teacher knowledge and sociocultural/feminist perspective, I review the literature pertinent to my research interests for the purpose of understanding of how and why teacher's change their practice. There are two main questions guiding this section; 1) What does educational research tell us about the components of teacher thinking and the factors impacting, guiding, and restraining its development? and 2) What do studies in higher education tell us about how teacher thinking needs to change to allow development toward a reformed inclusive pedagogy for science teaching? This section is in two parts, each addressing the above questions, respectively.

The perceived failure of the post-Sputnik science and math education reform initiatives reported in the early 1980s focused attention on teachers' thinking and actions. Around the same time, feminist theorists, motivated by the climate of equitable change that was felt in the 1970s, began putting out books and articles on, for example, how women learn and issues of gender in science and science education (Belenky et al., 1986; Keller, 1985;). The process-product approach to educational research, that had focused so long on teacher behavior and training, was not explaining adequately why earlier reform efforts had generally failed to produce reform-minded teachers and increase the numbers of females and minorities in the science pipeline.

I begin my review of the literature in the midst of the "educational crisis" of the 1980s with the work of Lee Shulman and his colleagues who proposed that subject matter knowledge and general pedagogical knowledge were missing a critical link, that is, pedagogical content knowledge (PCK). This proposition created a domain of educational research that has made many inroads into the landscape of teacher change by realizing that the choices teachers make about how to teach are both personal and socially situated. In the second part of the section, I introduce the framework of curricular transformation proposed by Susan Rosser to begin considering what needs to change about teacher thinking to create an inclusive environment for science learning and teaching.

Part One: Teacher Change

Highlighted in this part of Section III are research projects, theories, and ideas about the development of teacher knowledge structures, specifically, PCK and teacher's beliefs and values. This is accomplished through review of research theorizing that teachers' values and beliefs, and thus the development of their thinking, are steeped in and co-constitutive of culture and community. For teachers to change toward a more equitable vision of science for all they need to reflect deeply on their epistemological commitments to their core subjects and the notion that science is inherently "gender free" and consider how their values and beliefs impact their action in the classroom. This calls for the implicit to be made explicit. And, for a re-orientation of the sociocultural perspective toward accepting teaching as a way of being, where teachers (and educational researchers) realize how their being as teachers is only one way they are in the world and that their other roles or selves are significant and impact their thinking in the classroom.

Teacher Thinking: Knowledge and Reasoning Perspectives

> Effective science teaching is more than knowing science content and some teaching strategies. Skilled teachers integrate their knowledge of science content, curriculum, learning, teaching, and students...This special knowledge, called 'pedagogical content knowledge', distinguishes the science knowledge of teachers from that of scientists. (NRC, 1996a, p. 62)

Teacher thinking and expertise, for many years, was thought of as the interplay between a teacher's subject matter knowledge and their general knowledge of instructional methods, known as pedagogical knowledge. Lee Shulman (1986, 1987) suggested a third major component to the knowledge base of teachers, that is, pedagogical content knowledge. This component is the critical link between a teacher's subject matter knowledge and what they know about teaching. It informs, for example, biology teachers *how* to teach biology (domain-specific), biologic topics (topic-specific), and science in general Veal (1998, 1999). PCK itself includes two key elements, the transformation of subject matter for teachability and understandings of students' difficulties and varied conceptions of the subject matter. Shulman (1986) summarizes PCK as:

> Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others... [It] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning (p. 9).

Like many teaching and learning constructs in educational research, there is not one universally accepted notion of PCK. It has been conceptualized and re-conceptualized, modeled, and defined by a multitude of researchers. For example, Grossman (1990) enhanced Shulman's perception by including teacher knowledge and beliefs of the purposes for teaching specific material as a key elements of PCK. He describes the sources of PCK generation by extending them into the social dimension of pre-service observations of teaching, disciplinary major, teacher education, and classroom teaching experiences. Marks (1990) extended the PCK description by including, among others, the teacher's knowledge of instructional media. Cochran, DeRuiter, and

King (1993) re-termed PCK into pedagogical content knowing and embellished from a constructivist perspective on the fluid nature of its critical elements. Veal & McKinster (1999) created taxonomies for describing levels and types of PCK, as well as its expert attributes. Veal (1998,1999) developed models of PCK development synthesizing content, pedagogy, assessment, and context knowledge bases. Gess-Newsome & Lederman (1999) authored a book on the nature of PCK. Van Driel, Verloop, and de Vos (1998) summarize the connections being made between craft knowledge (see authors for overview) and PCK and posit that PCK is "an essential component of craft knowledge". They also effectively summarize the similarities among researchers' conceptions of PCK. The integrative process of PCK development can be portrayed through Shulman's model of pedagogical reasoning".

Shulman's work, along with colleagues, has shown that teachers must transform subject matter knowledge for the purpose of teaching. Wilson, Shulman, & Richert's (1987) "model of pedagogical reasoning" represents how teachers' experiences are transformed into pedagogical content knowledge. Using various forms of student assessment, both formal and informal, teachers reflect on their thinking and actions to make curricular and pedagogical changes. The model asserts that teachers' pedagogical reasoning transpires cyclically, from comprehension to transformation to instruction to evaluation and then reflection - leading to new comprehension. The transformation of comprehension occurs through 1) critical interpretation of subject matter, 2) the finding of multiple ways to represent the information (such as metaphors, activities, problems, assignments, or demonstrations), 3) adaptation of the information to student developmental levels and abilities, and 4) tailoring it for the specific students to be taught. In light of the important work of researchers from a sociocultural/feminist perspective, this model is limiting because of it operates in a purely cognitive realm. Feldman (2000), offers another model for teacher reasoning that, although originating in cognitive psychology, sets the thinking and actions of teachers squarely within a practical and social dynamic.

Feldman (2000) positions the deliberation of teachers in the practical domain by creating a model of practical conceptual change (PCC) after Posner, Strike, Hewson, & Gertzog's (1982) theory of conceptual change. His model is grounded in the social sphere, where teachers deliberate on ethical and moral questions that affect the lives of others and answer questions such as "What should be done?" (p. 608). He reworks the conditions for the accommodation of a scientific conception by individual learners into the conditions for the modification of a practical theory by teachers. Practical theories, originating from experience and ethical and moral lessons, act as "rules of thumb" and offer teachers reason and rationalizations for the choices they make in the classroom. However, they are not immutable, and can change through either "practice centered inquiry like action research or, more haphazardly, through experience" (p. 611). To accommodate a practical theory, a series of conditions are necessary. First, a teacher must be dissatisfied with a practical theory because "it leads to dissonance or dilemmas in practice" (p. 612). For teacher to accommodate a new practical theory, the teacher must find it sensible, beneficial and illuminating or enlightening. Those practical theories that are "more tenacious resist significant modifications" (p. 611) are likened to Kuhn's (1970) paradigms, and termed practical paradigms. Practical paradigms can operate as "the ethos of that community into which newcomers are indoctrinated" (p. 611), serve "as a template for problem solving in to which the particularities of the situation are molded... [and] be applied in situations for which they are inappropriate" (p. 612). As a result, they can extremely bias a teacher's ability to observe and act on problems or issues within a setting. Based on other works of Feldman (1997), practical paradigms, it seems, can lead to the creation of cultural myths (discussed further below).

Because they guide action, practical theories, I suggest, include a teacher's PCK. The studies briefly summarized below focus on PCK and its origins and effects on teacher thinking and student learning. Although I will not conduct such a formal analysis here, it is useful to read the following literature from a PCC perspective to consider the utility of the model. My rendering of this suggestion has concluded that the model, while needing further consideration of 1) the time differentials between a student developing conceptions of the natural world and accommodating a new scientific conception (Posner et al.,1982) and a teacher developing and changing usable practical theories and 2) how society and culture act similarly or differently on students' conceptions of the natural world and teachers' development of practical theories, offers a very compelling way to think about why and how teachers' PCK develops and what components of it may be malleable. The study by Gess-Newsome et al. (2001) discussed later in the section, represent how Feldman's model can be applied to teacher change research.

Studies have shown that new teachers have incomplete or superficial levels of pedagogical content knowledge (Carpenter, Fennema, Petersen, & Carey, 1988; Feiman-Nemser & Parker, 1990; Shulman, 1987). Russell (1993) refers to this as the "learning-to-teach dilemma" in which new teachers struggle to effectively put into practice teaching strategies that they really can only comprehend and use after they become more experienced. Hashweh's (1985, 1987) findings reveal (among other things) that science teachers planning curriculum out of their subject matter field encounter difficulty determining the most appropriate and useful pedagogical content knowledge for the subject. According to Carlsen (1987), teachers' frequent use of factual and simple recall questions have been found to be related to base levels of pedagogical content knowledge. These studies represent only some of the research on pedagogical content knowledge. They also demonstrate that pedagogical content knowledge is unique to a teacher's subject matter knowledge and changes with experience.

What is the experience of teachers as they reason about their pedagogy? Researchers interested in the links between society, culture, and teacher thinking began asking questions about the interplay of these factors and their impact on PCK and teachers' values and beliefs.

Teacher Thinking: Sociocultural Perspectives

Many fruitful research studies have illuminated the dynamic and interdependent connections between teachers' values and beliefs and the enacted curriculum. Values and beliefs are generally agreed to reflect and shape the social milieu and culture. The sociocultural perspective, in general, looks "closely at the interactions between teachers and the contexts in which they teach" (Feldman, 1997, p. 762). Studies have established that a teacher's values and beliefs are extremely persistent and have the capacity to control teacher thinking in ways that may constrain or foster efforts to reform teaching. For example, studies into science teacher's epistemological beliefs and how those beliefs affect teaching (Benson, 1989; Gallagher, 1991; Hasweh, 1985; Martens, 1992; Tobin & McRobbie, 1996) have lead to critical findings concerning the influence of beliefs on pedagogy and teacher change. Teacher beliefs not only influence teaching methods (Etchberger & Shaw, 1992) and beliefs about knowledge (Gallagher, 1991), but they can prohibit implementation of reformist teaching strategies and curriculum (Gess-Newsome et al., 2001; Martens, 1992) even more so than "situational factors/constraints" (Benson, 1989). Hashweh (1997) found epistemological beliefs to be "stable traits" and that teachers holding constructivist beliefs about knowledge are able to use "more effective strategies for inducing student conceptual change" p. 61). Grossman (1990) illustrates how values and beliefs constitute PCK. Adams and Krockover (1997) concluded that although novice teachers' ideas about pedagogy can be traced to their pre-service teacher education program, these ideas were not wholly accommodated into the teachers' knowledge structures. Instead, many teaching concepts were merely retained or modified and that other factors (observations as a percolate student, college academic coursework, and other experiences) had greater influence on their beliefs and pedagogical knowledge.

Feldman (1997), asserting an enhancement or reorientation of sociocultural perspective, initially summarizes two of its orientations. First, he reports on the work of Tobin & McRobbie (1996), Liston & Zeichner (1991); and O'Loughlin (1989) to characterize the sociocultural orientation that views teaching as dialectical interaction between teacher and social context. Then, reporting on Clandinin & Connelly (1992), he offers an orientation in that proposes that the context of teachers' work cannot be separated from the teacher.

However, before summarizing the main points of Feldman's work (1997), it is helpful to revisit the notion of culture because of its critical placement in the sociocultural perspective related to teacher thinking and values and beliefs. Culture can be identified in the broad domains of nationhood or global values as well as in the micro-environments of teaching and learning. Fetterman (1998) posits that culture can be defined in the cognitive realm as "the ideas, beliefs, and knowledge that characterize a particular group of people" or with a behavioral perspective focusing on the observable behaviors (patterns, customs, ways of life) of a group" (p. x). Teaching culture can be see as the "beliefs, values, habits, and assumed ways of doing things among communities of teachers" (Hargreaves, 1994.). Communities are accepted to be, as Blum (1999) states, "a grouping of persons with some degree of organization or a shared, recognized status" that "is taken to realize some positive value, and not simply to exist as a social entity or classificatory group (p. 135)." Communities exist with a "collective intentionality" (Searle, 1995 in Feldman, 1997) with "the capacity to share intentional states such as beliefs, desires, and intentions (p. 766)." The notion of collective intentionality is useful when thinking about and describing sociocultural perspectives of teacher thinking. We can, educator and layperson alike, reflect on experiences when our schools, teachers, or students exhibited and promoted collective intentionality. Writing across the curriculum, Drug Free School Zones, student walkouts, or curriculum re-oriented to better meet state standards and assessment expectations are some examples. Yet, accepting that collective intentionality exists within communities within cultures can give the impression of teachers benignly swimming with the tide of values and beliefs that engulfs them. And, that PCK develops thus reflexively. While the teacher knowledge and reasoning perspective focuses more on the individual teacher purposefully acting on her pedagogical beliefs, sociocultural perspectives seem to cast teacher thinking solely into the above mentioned tide of culture-induced values and beliefs. Feldman's (1997) teaching as a way of being perspective is refreshing attempt to recognize the person as teacher making choices in the midst of the tides. At this point, let us return to his treatment of the sociological perspective of teacher thinking.

The crux of Tobin & McRobbie's (1996) position centers around the existence of cultural myths (beliefs that act as referents for action within a setting) that are "conceptualized by teachers as beliefs that particular actions are the most appropriate for reaching particular goals in particular contexts…they can act as restraints… preventing teachers from taking what they believe would be appropriate actions in an ideal situation because in the particular context, other actions seem more appropriate" (Feldman, 1997, p. 762). Similarly, O'Loughlin (1989) presents an argument that "teachers hold beliefs that are socially constructed… and lead teachers to behave in certain ways, and to conceptualize teaching and learning in ways that add to the social construction of their beliefs" (Feldman, 1997, p. 763). Here we can envision, as a simple example, a biology teacher who, like science teachers, strongly believes that students should learn vocabulary before investigating a topic (general PCK according to Veal, 1998, 1999). Even when her students continuously fail to meaningfully learn the vocabulary by the end of the unit, she is resistant to change her sequencing of activities and the purposes in the lessons. Liston and Zeichner (1991) call for a mediation of this situation through personal reflection and inquiry. They posit that in order to reach the goals of effective teacher education, preservice teachers must be critical of how society and culture dynamically interacts with teacher thinking in general their personal teaching goals in particular.

Clandinin & Connelly's (1992) view of the context of teaching is slightly different than that of the authors discussed above. They view teachers' work as embedded in the curriculum and therefore not easily extricated and investigated. To them, the curriculum "is what happens in schools when teachers and students interact...[it] grows out of the lived experiences of teachers and students, rather than something that is delivered to the teacher to transmit or implement" (Feldman, 1997, p. 763). In their view, understanding the actions of the above-imagined teacher requires viewing her socially constructed values, beliefs, and activity in the classroom as part of the curriculum, in the way that the information on a page is part of a book. This requires focusing on the particular enacted curriculum when attempting to make sense of what happens during teaching and learning. Although I find this notion intellectually intriguing, it is very abstract and applying it to research or practical teaching scenarios would be challenging.

Teaching as a Way of Being Perspective

Feldman (1997), while finding the above sociocultural perspectives useful for understanding the context of what teachers do and why they do it, reconceptualizes the dynamic between society, culture, and teacher thinking with a new perspective, that is, teaching as a way of being. He suggests that a teacher is not simply the person doing the teaching but instead is immersed in understanding about being as a teacher in a setting. This immersion and understanding of self as teacher guides action. It also is made up of three varieties of wisdom; wisdom of practice (Shulman, 1987), deliberative wisdom, and wisdom-in-practice. Feldman considers wisdom of practice and deliberative wisdom as corresponding to the constructs of teacher knowledge structures and models of reasoning, and defines them as "knowledge in the form of propositional statements that are derived from practice" and "the ability to step out of practice and to reflect on what has occurred to make defensible decisions about what to do" (p. 769), respectively. Wisdom-in-practice relates to sociocultural and teaching as a way of being perspectives and "comes about through the understanding of one's own being and others in situations" (p. 769). Wisdom of practice is evident as teachers act on intentions and interact with students while thinking and learning about the situation of the moment. Believing all three varieties of wisdom to be important to good teaching, Feldman (1997) has offered a rich depiction of what it means to be a teacher and to teach. He effectively summarizes the significance of the wisdom of practice perspective when he writes:

> But just as we know that there is something missing when a sunset or a rainbow is described only with talk of refraction, diffractions and frequencies of light, there is something missing when we try to understand teaching without this perspective. (p. 771)

The teacher as a way of being perspective, and promotion that teachers not only teach and deliberate on subject matter through reasoned approaches but engage in situated understanding of their thinking and activity within the factors of time and space encircling them, broadens our sense of teaching and learning. It requires us to almost frame by frame consider the activity in a classroom in all its messy yet purposeful existence and intent. Not only that, it asks us to consider the microcosm of the classroom and the teacher in an ever widening circle of culture and place. In the following summary of a research study, I attempt to use the construct to extend the authors' implications.

Gess-Newsome et al. (2001), in an illuminating attempt to describe and understand the implementation of reform-based teaching, effectively summarize the issues and factors influencing teacher thinking and ultimately teacher change. I choose to feature this study because of its direct link to my research interests and the importance of its findings and subsequent hypotheses related to teacher change. It also offers a venue for thinking about application of the teaching as a way of being perspective.

From a sociocultural perspective similar to that of Tobin & McRobbie (1996), Gess-Newsome et al. (2001) report on <u>The Interaction of Factors and Their Impact on Scientist's Practice of Reform-based Teaching</u>. More specifically,

> Through the comparison of patterns of curricular enactment employed by three instructors in a single funded effort…this study…provides evidence to the question, ‘how do teachers’ knowledge and beliefs mediate reform?’ and informs the forth explanation by examining the impact of modifying structural and cultural contexts in order to enhance reform efforts” (p.8).

Gess-Newsome et al., define teacher thinking as “teachers’ knowledge and beliefs concerning teaching, teachers, learning, learners, schools, schooling, and subject matter” (p. 5). Their review of the literature fostered a theoretical creation of a model of teacher thinking and reform they call the Teacher-Centered Reform Model. In their model, teacher thinking is acted on by personal factors and structural and cultural contexts. The former includes “personal life experience, the nature and extent of teacher preparation and continued professional learning” while the latter is composed of “physical, temporal, and psychological characteristics of a setting (such as the arrangement of buildings, space, and furniture), schedules, subject area, grade level, and/or teacher team organization and physical space, books, tests, and teaching materials, and students”. These factors shape “the culture of a setting and thus influence teachers’ thinking as well as their pedagogical and curricular choices” (p.5).

An original assumption of the study was that the removal of contextual barriers (i.e. lack of funding/time/support) would increase the likelihood of reform implementation by the instructors. The results, however, find three professors enacting reform (or not) in very different ways and for different reasons. The authors hypothesize that although removal of contextual factors is necessary to create a setting that engenders reform, the “predisposition of teachers to change their practice” is more integral to the effort. Following Feldman (2000), they posit that the practical theories of the instructors “shaped and constrained” how reform was implemented. Also, for at least two of the instructors, they suggest that the professors were not at the outset dissatisfied with their teaching goals. This lead to poor or partial implementation of reform. They conclude that the study has illuminated the “multifaceted nature of dissatisfaction, namely, contextual and pedagogical, and the role of teachers' knowledge and beliefs as mediators of reform” (p. 39). In the implications section, they call for reform efforts that include a “process orientation” that places instructors in positions where they deeply and purposefully reflect on their values, beliefs, and practical theories, and consider how those constructs are situated within the goals of reform.

The teaching as a way of being perspective slightly shifts the focusing orientation of the research study summarized above. The perspective, it seems to me, centers humanity and its desires, irrationality, and earnestness appropriately in the gaze of educational researchers' attempts to understand teacher thinking and teaching. For example, when Gess-Newsome et al. define teacher thinking as "teachers' knowledge and beliefs concerning teaching, teachers, learning, learners, schools, schooling, and subject matter" (p. 5), they may capture the moment of the teacher in the context of teaching, but are omitting "other ways of being that include her relation to family, community, vocations, and avocations" (Feldman, 1997, p. 764 summarizing Stengel, 1996). Realistically speaking, how often are the lessons planned by teachers solely the result of supremely focused preparation time? Or lessons taught in a bubble - ignorant of the time constraints placed on busy lives as teachers, for example, rush from biology labs to meetings or family obligations? Further, in the model Gess-Newsome et al. advocate, personal factors and structural/cultural contexts are defined as factors dynamically impacting teacher thinking. Their definition of personal factors (see above) lacks a realization of the present and has causal implications that action proceeds life experiences and teacher preparation and will be affected by future and formal professional development. Does teacher thinking really develop so predictably? Humans, as idiosyncratic beings, do not always act on what we know. We can be unpredictable and creatively and effectively rash. The teacher may makes choices about her actions based on which students are absent, the weather, or how she feels on a certain day. How she feels may be the result of interactions with fellow faculty members, how late she stayed up the night before, or if her family is in crisis. Finally, the study supports a process orientation for reform efforts. I would add that as teachers engage in serious reflection "on their personal theories of teaching" that they explore not only their past and future practical theories and goals, but the reality that they have *goals of the moment* when they teach. And, although these goals may transcend taxonomic categorization, they may lead to an even richer and more accurate understanding of teacher thinking and change.

Teacher Thinking: A Feminist Perspective

Susan Rosser, in her books, Female Friendly Science (1990) and Re-engineering Female Friendly Science (1997) offers a theoretical model for thinking about the transformation of curriculum toward a more inclusive realistic vision of the nature of and role that females and men of color occupy in the scientific community (See Table 5 in Appendix A). Reflecting the Jackson and Hardiman (1997) model of social identity development presented earlier, she envisions curriculum transformation proceeding from a naïve to informed level of development. For example, stage one represents the traditional approach to science and the curriculum in which the absence of women is not noted and stages five and six represent and apply the science done by feminists/women by redefining and reconstructing its definition to include us all.

Rosser shares the notion of curriculum posited by Clandinin & Connelly (1992). From her experience directing and facilitating projects aimed at science inclusion, she views curriculum and its possibility of transformation as the outcome of the lived experience of teachers and their actions the result of personal development, awareness, progression, and stages of understanding – all of which reflect the socially constructed nature of their values, beliefs, and activity. For example, she writes:

> As I worked in projects and modified the stages to describe the way I saw curriculum transformation occurring in the science, especially biology, I recognized that the phases applied to more than curriculum. These stages describe steps of personal development through which individuals progress as they become aware of androcentric and ethnocentric biases in curriculum and pedagogy. In fact, as I suggested …I believe that an individual must progress personally through, or at least to, a stage of development before he or she can develop curriculum and pedagogical techniques at that stage. For example, a faculty member cannot teach a stage 6 course which the primary focus shifts from the white male experience to include women, men of color, and disabled persons, if she or he is only at the "add women and stir" phase (stage 2) in her or his own thinking. The syllabus and theoretical framework from which the course would be conceived undoubtedly would reflect the addition of a few famous women or a couple of examples of women's experiences to the course as she or he traditionally conceived and taught it. Without personally passing through the stages of understanding that the female is an exception, deviant, or anomaly when the male body or experience as a scientist is defined as the norm (stage 3), to a concentrated study of how the subject, problem, or research might be conceived if women, the female experience, or the female body were the focus or norm (stage 5), an individual could not conceive a curriculum or teach a class that was truly inclusive (stage 6).

Her findings suggest that curriculum transformation requires, similar to Gess-Newsome et al., serious consideration of the values and beliefs guiding PCK and classroom actions as well as attention to how being a teacher is part of a way of being for the person who teaches (Feldman, 2000). Her studies of faculty teacher change reveal that they are more likely to adopt new teaching strategies than change a syllabus or course content (1995, 1997). Curriculum transformation toward a stage six implementation, however, requires serious critique and re-working of a discipline's content matter by the teacher. This finding, I believe, is critical to the work of implementing reform in science education that is truly inclusive. It requires a real challenge to teachers' topic-specific PCK (Veal, 1998, 1999) that is deeply situated in their values and beliefs as teachers as well as their understandings of their place and role in the world as human beings. Gess-Newsome et al. allude to this when they discuss one of their participants', Albert. Although Albert's practical theories reflected reform goals, he "was limited by the pedagogical content knowledge that he had for his *topic of instruction* (my emphasis), and, more importantly, he felt no need to further develop his PCK" (p.33). Emphasizing this point takes us in the realm of the teacher reasoning perspective discussed earlier. This also speaks to a social justice issue as Kumashiro (2001) points out, "It is easy to add difference to the curriculum in a way that complies with hegemony" (p. 6). It may be that making substantive changes in the content of a course is a far more radical act than proponents of the "less is more" approach realize. This may be because we "desire the continuation of normalized teaching and learning practices" (Kumashiro, 2001, p. 6) that allows for the silencing of certain voices in the classroom.

Section III Part One Conclusion

Changing teacher thinking requires re-conceptualizations of how teachers dynamically construct understandings of the world and their role in it. Affecting change toward a new goal for teaching and learning is a complex political endeavor requiring, in part, teachers to critically reflect on their thinking and actions deliberately and openly through the lens of their teaching goals and those of change advocates. In this section, I have reviewed the literature asserting that teacher thinking emanates from the values and beliefs that are socially constructed. Teacher thinking is very complex and multidimensional, it is also modeled in different ways by different people. Shulman (1986, 1987) developed a cognitive model of pedagogical reasoning utilizing the components of teacher knowledge. Other authors (Adams & Krockover, 1997; Veal, 1998,

1999) have enhanced Shulman's conceptions of teacher knowledge by investigating the nature and components of PCK. Feldman (1997, 2000) situates teachers ways of being and teacher reasoning in the social sphere and offers the model of Practical Conceptual Change as a framework for understanding why and how teachers come to change their practice. A feminist perspective on teacher change emphasizes the necessity of critical reflection by teachers into not only why they utilize certain pedagogical techniques, but how those choices reflect deeply held values and beliefs about science, knowledge, teaching, and learning. Kumashiro (2001), in writing about anti-oppressive teaching for the disciplines, offers a sense of how difficult teacher change is, "...learning to overcome one's desire for the comforting repetition of normative knowledges, identities, and experiences involves learning to desire the discomforting process of unlearning. Desiring change involves desiring to learn through crisis" (p. 3).

Part Two: Transforming Science Education: The Role of Inclusive Pedagogy

> All students [must] have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students [must] learn these subjects by direct experience with the methods and processes of inquiry. America's undergraduates –all of them—must attain a higher level of competence in SME& T. America's institutions of higher education must expect all students to learn more SME&T, must no longer see study in these fields solely as narrow preparation for one specialized career, but must accept them as important to every student. America's SME&T faculty must actively engage those students preparing to become K-12 teachers; technicians; professional scientists, mathematicians, or engineers; business or public leaders; and other types of "knowledge workers" and knowledgeable citizens. (National Science Foundation, 1996, p. ii)

> In higher education, traditional signs of "knowing" the discipline – such as high grades in coursework and publications in peer-reviewed journals-are often equated with an ability to teach the discipline. Professors do not normally receive training in how to teach, much less in how to teach in anti-oppressive ways, and not surprisingly, by relying on past experience, commonsense, and models of former instructors, professors generally teach what is traditionally taught, in traditional ways. (Kumashiro, 2001, p. 10)

Like the mandate set forth in NSF's Shaping the Future report (1996), other calls have gone out to change the way undergraduate science education is conducted to improve and increase the involvement of females in science (Malcom, 1993; National Research Council, 1996b; Rosser, 1990, 1995, 1997; Sandler, 1996; Tobias, 1990, 1992). Initiatives for reform can be large scale, such as NSF's Experimental Projects for Women and Girls (NSF, 1993), or local, such as the inclusion effort at Maine's Bowdoin College or the Promoting Women and Scientific

Literacy project at the University of California – Santa Barbara. Along with these projects are research studies aimed at understanding the change process and potential for achieving "science for all" in higher education settings.

Influencing Scientists' Thinking about Inclusive Pedagogy/Reform

My review of the literature concurs with that of Bianchini et al. (1999) when they state "few studies…explore professional development opportunities for university scientists around issues of inclusion" (p. 2).) Research studies in the field describe faculty's professional development agenda (Muller & Pavone, 1998), the efforts of teacher educators to improve the gender equity of their program (Sanders, Campbell & Steinbrueck, 1997) and the limited success of large scale initiatives to effectively change the content of science professor's instruction (Rosser, 1995, 1997). Richardson, Sutton, & Cercone (1995) report success in making a geoscience course more female friendly by better connecting the content to students' lives and creating stronger relationships between them and their students.

Offering compelling findings to the issue is the study by Bianchini et al. (1999) looking at the first year of the Promoting Women and Scientific Literacy project. The purpose of the study was "to examine the perceptions and practices of 18 scientists who participated in a yearlong seminar series designed both to heighten their awareness of issues related to gender, ethnicity, and science, and to change their patterns of instructional practice accordingly" (p. 2). They report on three aspects of scientists' conceptions of inclusive science education, namely, their rationales for differential students success, the ways they structure, teach, and assess their courses to promote inclusion, and their views of the gendered and/or raced nature of science. Survey findings indicate that only a small majority of the professors felt that anyone can learn science and that scientific research was personally and socially influenced. In general, they endorsed a need for inclusive science education, agreed that content does not effectively represent minority viewpoints and involvement in science, and, of all the nature of science items presented most strongly considered science to be beneficial and creative. Interviews revealed more insight into the beliefs of the scientists. In general, the study's findings revealed the scientists beliefs that all students need to work hard, have the right attitude, and be self-motivated to succeed in science.

A small number of scientists adopted inclusive philosophies such as learning more about students' backgrounds and needs, intervening more in students' efforts, avoiding stereotyping students as "good" or "bad", and using student-centered learning approaches in the classroom. A majority discussed how student success was mediated by K12 experiences, family and cultural influences, and society. The scientists felt constrained to enact inclusive pedagogy because of contextual constraints like large class size, increased time and work load issues, loss of content material. The authors conclude from their work that inclusive pedagogy can only be achieved "if supported by the larger societal structures in which they are embedded" and "scientists [are] made aware that tensions exist between the goals, norms and practices of science education and the external forces that constrain students' aspirations, attitudes, and actions" (p. 32).

Mayberry & Rees (1997), while not solely focusing their writing on scientists' changing beliefs about females in science and science teaching offer insight to the discussion through Mayberry's involvement in course development. Their project entailed the design of a university course the connected the departments of geology, sociology, and women's studies. The authors conclude that "our effort to implement feminist pedagogy in an interdisciplinary 'science' classroom strengthened the ability of all students (and ourselves) in the class to play an active role in transformative learning and environmental, social, and political action"(p. 72). For Mayberry, the experience in the course made her committed to affecting change in her introductory geology course by making it more relevant to students' lives locally and globally. In addition, she reports that she is forced now to re-evaluate "many of the assumptions upon which her academic and personal development are based" (p. 73).

From these summaries of research related to the inclusion of females in science in undergraduate education settings, we see that changing pedagogy of faculty at these institutions requires a change in their beliefs about the nature of science and their role as educators, who can/should learn science, and how their efforts are viewed by their departments. In the end, as summarized in Part One of this section, change requires deep reflection and the removal of structural impediments and constraints. Below we shall see that a reformed pedagogy in science education that attempts to make science relevant and include females calls for a somewhat radical and acutely affective pedagogy known as inclusive pedagogy.

Reformed Pedagogy: Inclusive Pedagogy

Burbules (1989) separates the type of educational questions feminists research into two areas. The first area relates to the content learned in schools (i.e. is it inclusive with respect to the contributions and participation of women?) and the second focuses on feminine perspectives and ways of thinking (i.e. are there female ways of solving problems and making choices that have been traditionally ignored and denigrated?). Roychoudhury, Tippins, & Nichols (1995) expound on this second area. They describe the epistemology of feminist standpoint theory as the relevant theory through which reformists of science education can envision change.

Feminist standpoint theory propounds that knowledge generation is not gender-free. Instead, because knowledge is created socially, and the life experiences of females and males differ, gender differences exist with respect to knowledge generation. Females and males, therefore, have different ways of understanding and problem-solving within the shared experiences of life and learning. Science has developed and operates within a white male-dominated realm of experience. It is propounded to be objective, logical, and unemotional. Women's perspectives on science learning and problem-solving differ in their approach, goals, and progression and thus offer an enhanced methodology to this view of science (Keller, 1985). Female ways of knowing bring knowledge generation into a more holistic, personal, and issue-based realm. Without these perspectives in science, women continue to feel uninterested and negative toward the discipline. Without these perspectives in science, women continue to opt out (Seymour & Hewitt, 1997).

Feminist perspectives of a female worldview demand consideration in science education and women's everyday lives (Harding, 1991). A female worldview (Tobias, 1992; Belenky et al., 1986) determines how a student observes and makes sense of her physical and natural world. Understanding how females construct knowledge and how to make that knowledge relevant is a first step toward an pedagogy aimed at the inclusion of girls in science and math (Cobern, 1990).

How does inclusive pedagogy differ from traditional pedagogy? What does an inclusive science teaching pedagogy look like? Brickhouse (2001) suggests two significant components, it "acknowledges the cultural specificity of science and empowers our students to engage in science constructively" (p. 283). This entails a mindfulness about the teaching of subject matter created mostly by males and how authority influences content and how it is taught and learned. Such learning an environment must shed its traditional power structure, allow for and promote meaningful reflective sharing in many forms, and explicitly relate curriculum to the everyday lives of the students. The characteristics of this pedagogy will be defined under the major themes emerging from the literature: classroom power, discourse and relevancy. These themes are described further in the sections below.

Classroom power

Drawing heavily on the work of critical theorist Paulo Freire (1971), hooks (1994) describes her role as an educator. She admonishes the teacher who "doesn't care", and strongly urges pedagogic practice that exhibits care, interest, and concern for the individual student. She asserts that the interaction between student and teacher is critical to the student's learning, sense of belonging, and ultimately motivation to learn. This requires an elimination of the power role of teacher as unemotional authority figure and promotes teacher as mentor.

Hildebrand (1998) offers the concept of an enabling pedagogy, which draws on aspects of feminist, critical and hegemonic pedagogies. An enabling pedagogy works to balance the play of power in the classroom by realizing the inherent and necessary authority of the teacher yet promotes a broad program that effectively considers the affective, cognitive and sociocultural contexts of the teacher and students. In such a setting, students work with teachers to determine learning needs, relevant topics of study, and assessment strategies (Roychoudhury et al., 1995; Mayberry & Rees, 1997). Decision-making is shared within the available context of the setting.

Inclusive pedagogy requires such considerations to be made. Balancing classroom power is integral to an effective inclusive pedagogy. In power balanced settings, teachers see themselves as true advocates of student learning and are available mentors. They not only exhibit explicit care, interest, and concern (Noddings, 1995; Lyons, 1990; Sadker & Sadker, 1994) for their students' well-being, they believe that each student has important valid contributions to make to the class discourse (Gilligan, 1990) and act on that belief through curricular decisions. Besides bringing this human-element into the classroom, teachers who strive to balance power understand the history and nature of their science in such a way that it impacts how they teach their subject (Harding, 1991; Eisenhart et al., 1996). They see their students not as passive recipients of scientific truth, but active learners who can and should understand the changing nature of scientific methodology and theory (Belenky et al., 1986; Lemke, 1990). As a result, they give students voice concerning what is taught, how learning occurs and who can generate scientific knowledge.

Relevancy

An inclusive pedagogy promotes the need for the "everydayness" of science to be made accessible to students. Lemke (1990) believes that all students should understand science well enough to use it effectively in their daily lives. Traditional science-as-usual (Harding, 1991) education does not, however, makes scientific knowledge and thinking available to students because it promotes harmful myths of science that "favor the interest of a small elite" (Lemke, 1990, p. 129). As a result, science is often taught out of context, devoid of history or social implications, and has little impact on most students' personal and professional lives. Also, because science is taught through complex spoken and unspoken communications that portray its supposed extreme difficulty and specialty, science seems unattainable to the majority of students.

Roychoudhury et al. (1995) promote science teaching that is relevant to the lived experiences of females and meets their personal needs. Situated learning theory (Lave, 1992; Wenger, 1998), by offering authentic learning settings that can change how students' perceive themselves in the world attends to those experiences and needs and can promote a change in students' identities. For an inclusive pedagogy, this means placing scientific theories and concepts in their historical and social context and examining their contemporary impact at the personal and global level. It also means that teachers need to try to know who their students are with respect to their self and social identities in order to devise meaningful curriculum. Practical strategies to promote relevancy promote inquiry-based student centered learning. These entail the use of student-selected long-term projects/experiments (allowing for the personal bonding of student interest with project issues), the use and manipulation of scientific tools and materials, cooperative work groups, allowing students to negotiate and choose assignments for assessment of their learning within an authentic context.

Discourse

Ball (1993) writes that “Discourses are about what can be said, and thought, but also about who can speak, when, where and with what authority” (p. 14). Lewis & Simon (1986) analyzed the gender discourse within a college classroom. They conclude that, in order to counter a “patriarchic practice”, a struggle must be waged between academic (supposedly) objective discourse, and the articulation of our everyday experiences. The adherence to that struggle manifests itself when teachers “create a space for the mutual engagement of lived difference that is not framed in oppositional terms requiring the silencing of a multiplicity of voices by a single dominant discourse”(p.469). Lemke (1990) offers a multitude of instructional and philosophical reforms that make explicit the mystique of the dominant science discourse and allow students the opportunity to practice the everyday as well as "expert" language of science. The idea of making explicit the nature of science and dominant discourse opens the door for “other” voices to be heard.

A strong advocate of the female voice, Gilligan (1990) divulges the sublimated world in which girls’ true questions and thoughts exist. She considers what it means for women to be teachers of girls and how to recreate the teaching agenda and classroom discourse. She asks, “Whose agenda, what is important, what can be spoken and what is tacitly to be ignored - looked at but not seen, heard but not listened to? (p. 503).” Urging the creation of a new order for teaching practice, she promotes a pedagogy that is permissive in its discourse and allows girls to be honest and true in their public displays of knowledge and inquiry.

The consideration of discourse in an inclusive pedagogy calls for classroom atmospheres that utilize discourse as a means to uncover the mystique of science and transcend its traditional modes of information transfer, language, and discussion. This can be accomplished when, for example, students interact in groups that are mindful of dominance and isolation and teachers speak as a mentors in support of learning rather than bearers of scientific truth. A philosophical and practical implication of this is Hildebrand's (1998) hybrid imaginative writing. "Hybrid imaginative writing includes any blended genres that use scientific and/or factual genres (recounts, procedures, reports, explanations, expositions, discussions, etc.) in conjunction with imaginative or fictional genres"(p. 347).

A Framework of Inclusive Pedagogy Themes

Determining the themes of classroom power, relevancy, and discourse as central to an inclusive pedagogy leads to the creation of a model of their respective elements (See Table 6 Appendix A). My model, Elements of an Inclusive Pedagogy for Science, offers a way to think about specific and conceptual activities in a science classroom that support inclusive practices and question the teacher's underlying hopes, intentions, and practical theories guiding her action. Of course, this model, by its very creation, risks bounding inclusive pedagogy into a mere check-off list for assessing teacher's action in the classroom. I prefer to think of it as a tool useful for understanding the possibilities for the enactment of an inclusive pedagogy as well as a way to reflect on teacher's thinking about the nature of, and general activity in, the science classroom.

Summary

Because "schools shortchange girls" (AAUW, 1992), change in many disciplines of the educational process is necessary. Changing science education, from how it is conceptualized to how instruction is implemented, is underway in K-20 education. This paper has summarized the theoretical underpinnings of the science education reform movement and considered the practical nature of their implementation. We see how scientific literacy drives mainstream reform efforts yet many educational researchers are critical of its continuing focus on content acquisition and representation by students. Feminists advocate change that leads to not only an equitable representation of females in the scientific community of practice but a realization of how they can and have changed the scientific endeavor.

Again, the practical implications of this position are difficult and complex. This paper has focused on understanding how the scientific culture and community inhibits equality in the sciences through its normative structures, values, and beliefs. These factors explicitly and implicitly retain females and men of color on the margins of science. One way this occurs is the integration of these factors into the identities of students and teachers alike.

Raising consciousness of this phenomenon for teachers and students can offer insight into how change can occur. This paper has explored the literature on teacher change in an effort to understand the impediments to changing practice and to envision a methodology that can assist us in understanding the change process. It has also framed the argument for change toward a more inclusive pedagogy for science education and offered a theoretical base for its purpose and implementation.

In my next chapter, Design and Procedures, I outline and describe my proposed study aimed at understanding the conditions necessary to instigate change in the pedagogy of a professor teaching a reformed introductory level science course toward a more inclusive practice of science for all.

CHAPTER 3

DESIGN AND PROCEDURES

Introduction: Overall Approach and Rationale

> "To promote agency rather than alienation of scientists, professional developers must raise awareness of gender and racial bias in the science while simultaneously respecting multiple, dissenting voices and experiences – a difficult task indeed. Recommending scientists look more closely at the intersection of views of students, classroom practice, and the nature of science is a potentially fruitful first step. Providing space for scientists to develop their own response to equity issues from their experiences-in-interaction-with-feminist-research will help create a more just and equitable science education for us all." (Bianchini et al., p. 34)

The purpose of this study is to increase understanding of the conditions necessary to facilitate change toward a more inclusive pedagogy by professors of introductory level science courses. My study entailed in-depth probing into the values and beliefs held by two professors about science, science education, teaching, and learning and affords them opportunities to research their practice through an assisted action research project (Feldman, 1997, Stenhouse, 1975; Carr & Kemmis, 1986; Gess-Newsome et al., 2001). Promoting an emancipatory methodological approach (Lather, 1991), I accept that my work is not value-free and seek to "increase awareness of the contradictions hidden or distorted by everyday understandings" (p. 258). The findings of the research are not just my interpretations of everyday understanding of the professors' situations because the assisted action research model provided a mechanism for participant empowerment. Questions, data collection, analysis, and interpretation cycled through multiple understandings as the participants and I collaborated to find meaning in their situations. My goal with this approach was two-fold; to empower the professors' toward sense-making about the supports and constraints toward transforming pedagogy and to raise awareness about the emancipatory role that they can play in nonscience majors' thinking about science. Using data from student interviews extensively as a catalyst for questioning the meaning and purposes of everyday classroom activity promoted my latter goal.

The Nature of the Methodology

Assistance with the action research project is offered by orienting me, the researcher, in the primary role of knowledgeable other or critical friend to engage the professor in "collaborative sustained conversation" (Feldman, 1998) and in the secondary role of research assistant/co-researcher to conduct most of the data gathering responsibilities. This unique relationship is designed to foster teacher change and illuminate the personal and contextual factors impeding or supporting the change process. Gess-Newsome et al. (2001) support a research model of this type, suggesting that

> faculty [be] placed in a position to seriously reflect on their personal theories of teaching, systematically compare their beliefs and practices to those advocated by the reforms, and to spend time collecting data on the efficacy of their teaching methods to achieve the goals they value...[this requires] time and a knowledgeable other to facilitate learning. A knowledgeable other is needed to ask the essential questions that will make explicit personal theories to provide resources that will appropriately challenge beliefs, and to provide support when individuals... are ready to explore new beliefs and instructional practices (p. 38).

Using a variety of qualitative methods, my research design exhibits elements of both a critical case study and a critical ethnography. Rossman & Rallis (1998, p. 71) maintain that the former will "illuminate the reader's understanding of the setting...[and extend] comprehension of some complex set of events or circumstances" while the latter requires "long term, sustained participant observation", "face-to-face interactions", a focus on "how interactions shape meaning in particular settings", and "the study of cultural groups." Yin (1991) defines a case study as a situated exploration of a contemporary phenomenon. My work intends to extend understanding about teacher change at the college level through in-depth study particular science professors teaching introductory level courses. Early on in the project, using descriptive and inductive modes of data collection, I sought to understand what is going on in this case by asking, "What are the key actors doing? Why are they doing it? What do they believe and value? What is tacit in the setting? How do their values and beliefs shape their actions and understanding of those actions?" (Rossman & Rallis, 1998, pp. 63, 83). These questions seek to illuminate the culture of the setting and its members' various group and individual identities. Later in the study, from a more critical perspective, I describe how the beliefs and actions of dominant actors in the settings perpetuate or interrupt patterns of dominance and exclusion. Using multiple and flexible data gathering techniques through an action research strategy result in a description of how "changing actions, activities, or interactions" (Rossman & Rallis, 1998, pp. 83) came about and affected the setting and its members.

Using the above research genres, my work describes the process of teacher change from a feminist sociocultural perspective. It examines how the teacher, situated in the variety of sociocultural communities through which she enacts her personal and academic life, makes sense of, rethinks, and potentially chooses to implement a more inclusive pedagogy. My findings explore the limits and constraints of teacher change within the setting, probing into the personal values and beliefs guiding action in the classroom. Further, through "face to face interaction", it challenges the professor to understand the origins of her values and beliefs and critically examine the efficacy of their influence on pedagogy. A major source of data the professor used for such reflection originated in the thoughts, feelings, and ideas of their students. An intriguing and challenging aspect of this research was describing how those voices were heard and responded to by the professors.

The Major and Guiding Questions of the Study:

Major Questions

1. How does placing the professor in a position to conduct an assisted action research project help to foster teacher change conditions?"
2. How do the practical theories guiding the professors' teaching foster or impede inclusionary practice?
3. What necessary conditions of the teacher change process toward an inclusive pedagogy emerged from my study?

Guiding Questions

A. What is going on in this case?

B. What are the key actors? What are they doing? Why are they doing it?"

C. What deeply held values and beliefs guide actions, interactions, and activities?

Project Setting

The setting of this project is one of 15 Collaboratives for Excellence in Teacher Preparation funded by the National Science Foundation in 1996 to prepare more science teachers, and for them to be more ethnically diverse and better prepared to teach science in elementary and secondary schools. Over one hundred professors joined the Collaborative with the hope of utilizing greater student-active learning strategies in their teaching. A portion of the Collaborative's (1995) proposal abstract describes its intention:

> A major component of [the Collaborative] will be the support of discipline-based curriculum teams which will develop new and revised college science and math courses. In addition to college faculty, these teams will include K12 teachers and education professors who are experts in the new pedagogy. Because most teachers teach the way they were taught (Shymansky, Hedges, and Woodworth, 1990), these courses will model the most effective teaching strategies and tools: cooperative learning, investigation-based teaching, educational technology, new assessment techniques, and opportunities to teach (NCTM, 1991; NRC, 1996a; AAAS, 1993). Since the best way to understand the nature of science is to actually do real science, we will offer all undergraduates the opportunity to conduct original research. [The Collaborative] will use these established teaching strategies to reform the way we teach science and mathematics to future teachers.

The research study described in this paper specifically addresses the first goal of the project that is to:

- Assist college science, mathematics, and engineering faculty in learning and adopting new pedagogic approaches, especially in courses for future teachers.

My study also linked to the proposal's stated Need #3:

> Many minority groups continue to be under-represented in science and mathematics education (Oakes, 1990). Nationally, 30% of the students belong to under-represented minority groups, but less than 10% of the science and math teachers are from these groups. (Weiss et al., 1994; NCES, 1994). Over the past 20 years the number of women teaching secondary mathematics has increased to approximately half the total, but only a third of the high school science teachers are women. The Massachusetts statistics are similar to the national data (MA Dept. of Ed., 1996). We need to recruit and retain women and minority students in the appropriate college majors and into teaching.

Acting on this need led the project to develop and implement summer and semester sessions for college SMET faculty that introduced and explored with faculty the constructs of cooperative learning, inquiry-based learning, alternative assessments, and providing students with teaching opportunities. The approaches were guided by a constructivist theory of learning.

I became interested in critically exploring the emerging data from some Collaborative courses that course reform benefited everyone equally and questioned whether the professors' global objectives of scientific literacy for all were being met. Through two pilot studies conducted in two courses, I sought to understand the experience of females in introductory level Collaborative courses and the supports and constraints acting on the teacher change process.

Those studies led me to identify two areas of interest centered on the teacher change process:

- How feminist theory and a feminist and/or inclusive pedagogy can inform and link to national reform efforts as manifested by the Collaborative.
- The supports or constraints to a professor's adoption and implementation of an inclusive pedagogy.

These interests launched me into an extensive literature review summarized in this dissertation and led me to the design of a research methodology I call assisted action research.

<u>Selection of Participants</u>

I worked closely with two science faculty at a large northeastern university to better understand the conditions of teacher change toward an inclusive pedagogy. Both professors became affiliated with the Collaborative in the latter stages of its funding and were not part of the original professional development sessions offered in the mid-90s that catered to over a hundred professors. Dr. Mary Gibson became a Collaborative Fellow the semester I began researching her course through my urging as it would offer her additional teaching support and funding for her course. She attended monthly Collaborative seminars that promote her investigation, reflection, and accommodation of a reformist-based pedagogy and teaching strategies. I met her through her colleague, Dr. Liza Richards (a consultant to the biochemistry department). Dr. Richards attended a workshop I co-presented on inclusive pedagogy and felt that my work would assist the development of the new course that Dr. Gibson had initiated develop on. After meeting with Dr. Gibson and discussing the course and project, she agreed to become involved.

Dr. Jim Willis became affiliated my project also through one of his colleagues. He became associated with the Collaborative when he joined the geology faculty in 1999 and began meeting with participating professors to discuss the logistics and goals of the course he would teach. One of these professors assured me that, based on their meetings, Dr. Willis shared the Collaborative goals for undergraduate science education and was very motivated to learn about and enhance his teaching. I called him to initiate contact and we met to discuss the project. As a new faculty member who would be teaching a large lecture course for the first time, he agreed to participate in my study in order to better understand issues of teaching and learning in the course.

Two professors were selected in an attempt to 1) insure the availability of research data and 2) broaden the range of professor variation in the study. The professors are alike in that they are explicitly committed to improving their instruction. In some ways the latter could be considered a limitation to the study, however, I believe they are good choices because most professional development efforts in higher education, right now, only cater to those interested. Findings my study therefore have more relevancy to reform efforts with like-minded participants. Future research can explore how to motivate others to become interested in issues of teaching and learning and science education reform.

Along with the professors, students in their courses participated in the study. Students were interviewed, asked questions through email, and surveyed throughout the project. I selected students based on whether filled they out the volunteer portion of the student questionnaire completed for me at the beginning of the semester (See Appendix B, Student Questionnaire). I paid students for the interviews. In Dr. Gibson's class, all nine students that volunteered were interviewed. Dr. Willis' class of six hundred and thirty-nine met in two sections. I handed out surveys to section one and two hundred and thirty-five students returned them. Out of that group, eighty-seven volunteered to be interviewed. I selected twenty-five students to contact based on gender and major. Wanting to continue with work from a pilot study exploring the experience of females in Collaborative courses, I chose more women than men to be interviewed. I also attempted to choose students from a variety of majors. Of the twenty-five students I contacted, fifteen agreed to make the commitment to my project.

All participants that agreed to be interviewed read and signed an informed consent letter (Appendix C). All names used in this paper are pseudonyms to protect the rights of the participants.

Data Gathering Procedures

The data gathering procedures for this project followed a mixed methods approach and was conducted in two major phases that are discussed in detail below. I utilized the data collection method of constant comparison analysis and triangulation (Cronin-Jones, 1991; Glaser & Strauss, 1967). Phase I proceeded as a mini-ethnography of the cases under investigation and is a descriptive study focusing on culture and members' beliefs and values as they relate to science and science education. The goal of this phase was for me to experience the setting, analyze its dimensions and sequences, and describe it. The goal was accomplished by observing classes, interviewing and surveying the professor and students, and reviewing course materials. Data was recorded in four types of research notes; field notes, personal notes (containing feelings, reactions, biases, etc. of the unfolding setting and its participants), methodology notes (describing changes to my method and my rationale), and theoretical notes (to capture emerging hypotheses). Interviews were audiotaped and transcribed. During this phase, data production resulted in participant quotations, setting descriptions, and document excerpts that offered a framework for understanding the context of teaching and learning.

My primary role during this phase was one of *facilitator* as I "construct[ed] a supportive and safe normative environment with [the participants] and help[ed] them explore issues with their own vocabulary, their own metaphors, and their own ideas" (Carspecken, 1996, p.155). The professor was also asked about any personal and/or contextual factors impacting the start of the course in unique, puzzling, and potentially important ways.

Phase II of the research added a more explicit critical perspective to the research design. Using the strategy of an assisted action research project it continued to use the data collection modes and methods characteristic of ethnographies and case studies described above. In this phase, questions were asked about the case descriptions of culture and identity that focused on issues of power and voice embedded in the described values, beliefs, and actions of the participants. The goal of this phase was to engage the professors in critical reflection about their practice and challenge them to view their reflection from a feminist and sociocultural perspective. This was accomplished by incorporating an assisted action research project into the setting and engaging them in "collaborative sustained conversation" (Feldman, 1998). These conversations challenged the professors strongly held values and beliefs about science, science teaching, and equitable learning. Data collection was similar to Phase I and was flexible enough to respond to the goals of the developing action research project. Conversations with the professors were audiotaped and/or documented as field notes. Data production included additional participant quotations, setting descriptions, and document excerpts that described the developing story of teacher change and its ramifications on the setting and students.

Phase One: Introduction

Phase One asked the questions, "What is going on in this case? What are the key actors? What are they doing? Why are they doing it?" (Rossman & Rallis, p. 68). It proceeded based on the TCSR Model described earlier in order to explore the general context of reform within the setting. It involved making known the constructs of those studied, that is, the teacher and student roles in a reformed introductory level science course. I was interested in studying their general beliefs about the context of their action (teaching or learning science) and ways of being (Feldman, 1997) as they interacted with the cultural context. This required adherence to the personal and contextual factors that guide and frame thinking and action. Specific data sources, discussed in detail below, included:

Faculty questionnaire

One semi-structured faculty interview

One student survey

One semi-structured interview with students

Classroom observations

Phase One data collection placed me primarily in the traditional role of researcher as instrument of the research. My nature however, tends to position me often in the role of friend and learner when I ask questions. Of course, reflexivity was vital in order for me to clarify how my biases, assumptions, and expectations influence the data I choose to collect and how it is recorded. I began this research with an etic perspective and gained more understanding of an emic viewpoint as the research evolved. Although I never gained full participation in the setting as a student or "co-teacher" to the professor, I tried to minimize the differences between myself and my participants over time in order to fully describe the culture and identities influencing learning and teaching intentions.

Phase One Data Sources

Nature of Science, Teaching, & Learning Faculty questionnaire

For the purposes of understanding the range of the professor's beliefs concerning the nature of science and science education, each faculty member was asked to complete a questionnaire (Appendix D, Faculty Questionnaire) prior to the interview. The questionnaire is a modification of one utilized by Bianchini et al. (1999) to "assess scientists' perceptions related to science students' interests and abilities, inclusive science education practice, and the nature of science" (p. 10). The questionnaire utilized, in addition to space for additional comments, a five point, Likkert-type rating scale with the following choices:

1= strongly disagree

2= generally disagree

3= neutral

4= generally agree

5= strongly agree

The questionnaire (and proceeding interview) provided data through which to support my inferences and offer the professors insight and opportunities for discussion about how I framed their responses.

Faculty Interview

Semi-structured interviews were conducted with the professor prior to and following the Spring 2002 semester. These interviews served to "elicit the participant's worldview" by "[posing] open-ended questions followed by requests for elaboration" (Rossman & Rallis, 1998, p. 124). The organization of the interviews followed an open-ended and flexible interview protocol as suggested by Carspecken (1996). The protocol suggests formulating concrete lead off questions/scenarios that will get at the participants' implicit theories guiding action with follow up questions designed to help them generalize and theorize about their answers.

The focus of the introductory faculty interview was to collect data that tells a story about the professor's experiences as a science learner and teacher. The professors were asked a set of lead off questions about their history/experiences in science and teaching (Appendix E, Introductory Faculty Interview).

Student Questionnaire

All students in the microbiology course and half of the students in the geology course were asked to complete a questionnaire (Appendix B) at the beginning of the semester. Questionnaire statements made about the course were derived from the introduction statements from the course syllabus. Nature of science-type questions were derived from the Collaborative end-of-the-semester survey used a few years earlier and my own interest in topics related to females in science and student interest in science. The questionnaire informed me about the demographics of the class, students' year/major, reason for taking the class, students' beliefs about the nature of science, teaching, and learning, and students' interested in being interviewed for the study. The questionnaire, in addition to space for additional comments, utilized a five point, Likkert-type rating scale with the following choices:

1= strongly disagree

2= generally disagree

3= neutral

4= generally agree

5= strongly agree

Student Interviews

Initial 45 minute student interviews (Appendix F) were broad in scope as students informed about their 1) experiences in science, science courses, the college classroom environment, 2) present and future personal and career goals, 3) connections between science and their lives, and 4) expectations about the course and its potential to impact their present and future lives. Student responses to the questionnaire were discussed and requests for elaboration were made.

Classroom Observations

Throughout the semester attended classes and alternated my role between participant observer and passive recorder of events/discourse/interactions. The goal of the initial observations was to "produce a thick record of social routines in as naturalistic a form as possible" (Carspecken, 1996, p. 53). Close attention was paid to the interactions between teacher-student (both formal and informal), student-student, teacher-researcher, and student-researcher as well as how the participants interacted with class materials (text, papers, artifacts) and technology. Using Carspecken's (1996) notion of "the method of priority observation", I utilized a flexible observation schedule that rotated my focus between individuals and groups for periods of time.

Phase Two Introduction

Phase II commenced approximately five to six weeks into the semester. In this phase, I collected data integral to describing the requisite conditions of the teacher change process toward an inclusive pedagogy. In my field and research notes, I focused on the following questions;

What deeply held values and beliefs guide actions, interactions, and activities? (Rossman & Rallis, 1998, p. 68),

What actions perpetuate exclusionary practices in the science classroom and how can they be interrupted and changed?

What difference does changing actions, activities, or interactions make to the group or the individual? Rossman & Rallis (1998, p. 68).

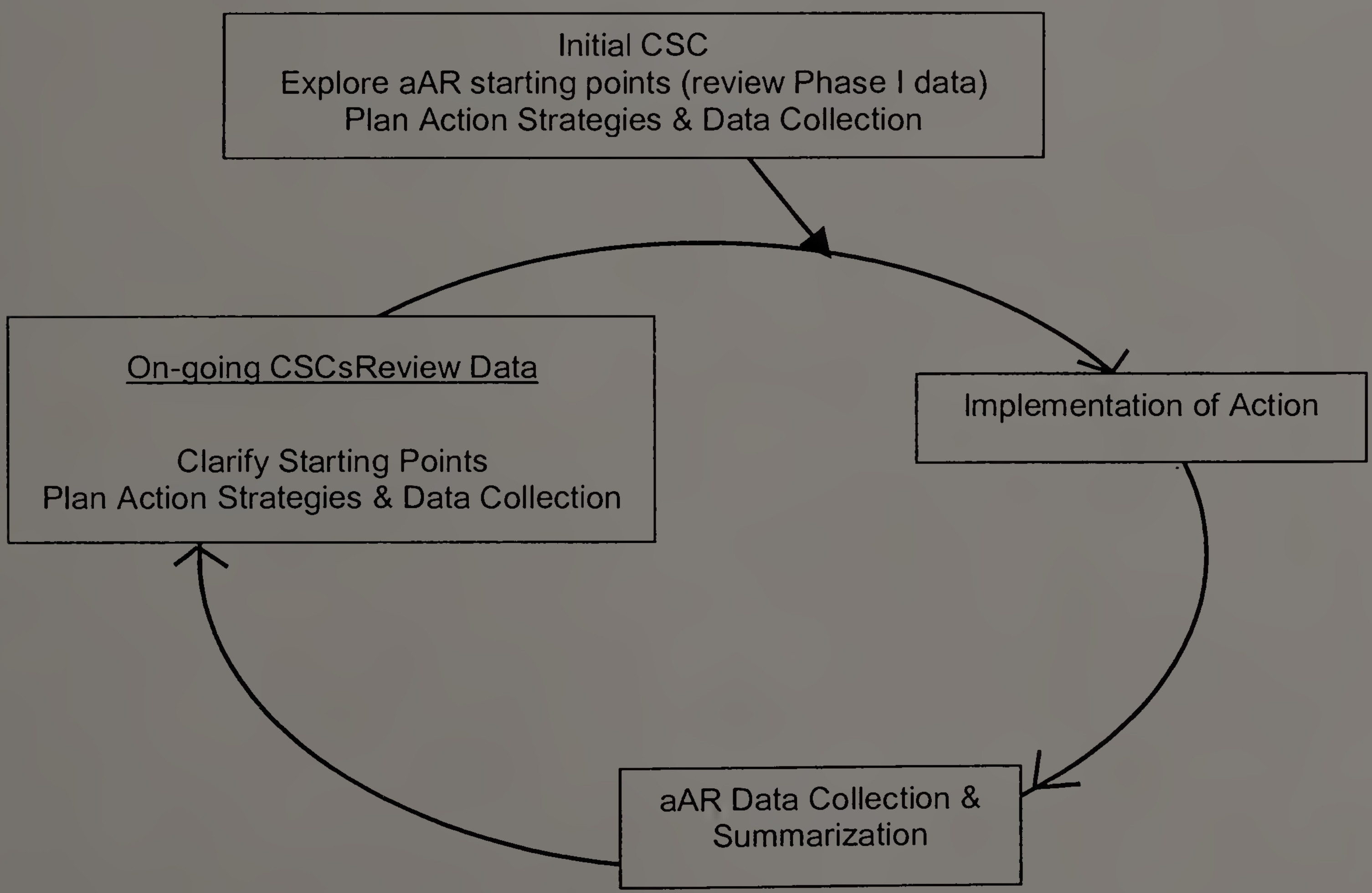
I proceeded to answer these questions by imposing an "intervention" or "change catalyst" into the setting that focused on teacher thinking and action and collected data using a variety of techniques from multiple sources. This was accomplished using the assisted action research (aAR) cycle.

The aAR Cycle

The aAR project can be visualized through a cyclical representation (Figure 1). This representation, as well as the proceeding explanation, has been adopted from Altrichter, Posch, & Somekh (1993). The cycle began with an initial collaborative sustained conversation (CSC) between myself and the professor that intended to find starting points for the projects during the introductory interview. The conversation focused on any interests, difficulties, and unclear situations or discrepancies that existed with the course.

Our initial CSC lead to implementation of action strategies by the professor and myself. In general, these are practical actions developed as a result of theories about practice gained from action research (Alrichter et al., 1993). As the aAR cycle continued the strategies took on more depth and complexity. The implementation of the strategies can be likened to hypothesis testing and thus the next step of the process required me to collect data to determine if "the desired effects come about without unexpected negative side-effects" (Altrichter et al., 1993, p. 158). Following my data collection and subsequent data summarization, we continued the aAR cycle with the on-going CSCs to clarify starting points, plan action strategies, and collect/summarize the next round of data. The cycle culminated with a final CSC (final interview)during which we deliberated on the process and its findings and discussed potential future action research activities for the professor.

Figure 1: The aAR Cycle (adapted from Altrichter et al., 1993)



Using action research as a strategy through which to understand the culture and identities within the setting and how their interplay influences action allowed for a somewhat open-ended and emergent data gathering stance. It permitted me to collaborate with the participants to determine "what is important to inquire about and how tightly [to] structure [the] techniques" (Rossman & Rallis, 1998, p. 120). The dynamic nature of this design, though ambiguous, was integral to answering my research questions. Data sources (discussed in more detail below) included;

Twenty-three classroom observations in Dr. Willis' course

Eighteen classroom observations in Dr. Gibson's course

Four to Five collaborative conversations with the professors

Multiple email correspondences with professors and students

Two semi-structured interviews or one semi-structured interview and a focus group interview with student participants

Review of material culture from the course

The intent of this phase was to engage the professors in critical pedagogical reflection. I accomplished this through an aAR project. In the primary role of critical friend, my responsibilities included, "[asking] provocative questions that help others define expectations and intention, [helping] them realize when their expectations for themselves and others are too low, and [telling] when their actions don't match their intentions" as well as "...[raising] questions...[critiquing] the work, [and] nudging the teacher to see the lesson or unit from different perspectives" (North Central Regional Educational Laboratory). These descriptions effectively characterized my intent as a critical friend and allowed me to infuse my knowledge about inclusive science education into the collaborative conversations between the professor and myself.

My secondary role in the aAR project was to relieve the professor of data gathering and summarizing responsibilities. Thus, I was also collaborator and research assistant. However, in the action of collecting and summarizing student reflection data for the professor, I also assumed the role of facilitator and advocate for their ideas. It was suggested that in this situation I acted as a "neutral broker" (Elliot, 1988) because of my "neutral" stance of not favoring the professor's ideas over the students' or visa versa. However, although the term is conceptually intriguing, I found it semantically problematic because it implied that I did not have an agenda or that the research was more phenomenological and holistic than it was. As a project based on feminist theories about science and learning it had a very definite set of lenses that guided my questions, data collection, analysis, and how I focused my participants' sense-making about the setting. My position as a university researcher inevitably introduced issues of power and voice into the project. As a researcher, though I strive for a high degree of neutrality in my efforts to be descriptively accurate, I understood that personal bias, subjectivity, and perspective influenced my decision-making and interpretations. Therefore, I found the research roles of collaborator, critical friend, facilitator, advocate, research assistant the most suitable for explicitly making my subjective attempts at neutrality known.

It is important to note that I did not take on the role of teacher educator about action research for the professor. I adopted the role of collaborator/research assistant in part so that the project could move along and data was collected/analyzed within the time frame of the project.

Phase II Data Sources

Collaborative sustained conversations

The aims of the collaborative sustained conversations are to 1) continuously clarify starting points, 2) plan actions strategies, and 3) plan additional data collection. Starting points for the aAR projects began as a first impression of the setting and changed over time as we came to a "deeper understanding of the practical theories which govern our actions" (Altrichter et al., 1993, p. 45). As our understanding evolved we chose and created action strategies to affect the setting and illuminate the practical theories at work.

Through our collaborative sustained conversations, as we reflected on the collected data, I engaged the professor in explorations of the ways that classroom power can be shared, alternative discourses can be valued, and students' sense of course relevancy can be heightened. These are deep underlying classroom constructs that comprise many of the major elements of an inclusive pedagogy and act on and within the teaching and learning culture of the classroom. As a critical friend, I attempted to focus and challenge the professors' sense making with questions that went beyond traditional teacher reflection on action. The usual question, "How might this activity have worked better?" instead assumed a critical stance that was conscious of the nature of science, the "science as usual" phenomena, and equity issues in the classroom.

Classroom Observations

Multiple classroom observations were conducted during this phase. They were carried out similar to Phase I observations in that I varied my role between participant observer and passive recorder of events/discourse/interaction. The focus of the observations developed and changed over time as the projects were conducted.

Student Reflections: Whole Class, Individual Interviews and Focus Group

Student reflection data was collected following the implementation of an action strategy. During the Phase, I emailed students with questions about what was occurring in the course based on the issues raised by the professors. An end-of-the-semester survey was utilized to elicit additional questions and issues about the course, particularly around the concept of relevancy. At the end of the semester, I used the 45-minute semi-structured interview approach with seven students. Focus groups with the remaining five sets of students (three to four per group) allowed me to investigate how groups of students made sense of the professors' thinking and actions throughout the semester. One student from each class was not able to participate in a final interview or focus group.

Data Analysis Procedures

Data analysis focused critically on the ways that "science as usual" (Harding, 1991) and "science education as usual" is maintained or interrupted in the complex setting of a college science classroom. From a critical ethnographic genre, I looked closely at these phenomena by exploring the cultural and personal values and beliefs held by the students and professors as they thought and acted in the setting. Using a case study approach (Yin, 1991) and inductive analysis (Lincoln & Guba, 1985; Miles & Huberman, 1994) I organized, categorized, and framed the collected data.

Data Reduction

Data reduction began at my first conception of the study and continued into the writing of the final report. It is "the process of selection, focusing, simplifying, abstracting, and transforming the data that appear" (Miles & Huberman, 1994, p. 10). Using a modified grounded theory approach (Cronin-Jones, 1991; Glaser & Strauss, 1967), data was be examined for regularities, patterns and assertions (statements describing patterns) and compared in order to support or refute assertions.

Data was coded to determine its descriptive and/or inferential meaning. In Phase I, code assignments were mostly inductive. The emergent coding categories of this phase provided me with important categories that helped to guide Phase II. data reduction. For example, data collected about the professor's beliefs about how students learn provided me with coding categories that explicitly illustrated the professor's teaching strategies. Over time, coding categories broadened to include, where applicable, descriptive, interpretive, and patterned meanings. First-level coding, in most cases, lead to the construction of patterns that were tested against new data. As such, both master and sub codes emerged and were defined. Qualitative software analysis tools provided by Atlas ti assisted my efforts.

Data Display

Data was organized on matrices and/or network displays (Miles & Huberman, 1994). The initial findings of Phase I used partially ordered displays known as a context charts or checklist matrices to summarize coding categories. Data collected from Phase I and Phase II utilized both time-ordered and conceptually-ordered displays to explore and summarize collected data. Time-ordered displays illustrated the role that the change catalyst, aAR, had on the setting and "preserve[d] chronology and illuminate[d] the processes occurring" (Miles & Huberman, 1994, p. 111). Conceptually ordered displays assisted my descriptions of the nature of the aAR projects. Cross-case displays focusing on degrees of effect were also useful in helping to determine conditions of teacher change toward an inclusive pedagogy that represented both settings.

Conclusion Drawing & Verification

The findings of the research aid in our understanding of integral components of meaningful educational reform in this setting and have broader general implications for science education. The result of my study is narrative, including charts and diagrams that illuminate necessary conditions of the teacher change process. It also highlights the roles that culture, identity and the aAR strategy played in the change process.

My research findings achieve credibility as a result of data triangulation, long-term engagement with the setting and its participants (Lincoln & Guba, 1985), and use of member checks (Miles & Huberman, 1994). Triangulation of data was accomplished using my field/research notes, transcripts from interviews/conversations, and classroom observations to make meaning of the thought and action that occurred during the project. In describing my setting, analyzing data, and articulating conclusions I draw on and explicitly cite these data sources. My prolonged involvement in the setting was accomplished through numerous interactions with participants and their learning setting. This afforded me understanding that is represented through in-depth descriptions. For example, Chapter Four includes fictionalized narratives, or vignettes, that help to expose the character of the professors' settings and their actions in the classroom.

Member checks afforded further corroboration of emerging patterns and conclusions. During the aAR projects, we collaborated on the meaning of the data. Chapter drafts were reviewed by the professors who were given opportunities to change, question, or dispute findings, analysis, and conclusions. In the study with Dr. Willis, I twice cross-checked findings and conclusions with him as well as another member of his department. In Dr. Gibson's case, Dr. Richards often clarified served in this role, clarifying my questions and suggesting alternative perspectives. I cross-checked findings with students as well. Email correspondences were utilized to ask students questions about issues and findings that arose during the project.

In addition, cross case displays were used to enhance generalizability as I attempted to move from "locally causal" to "translocally causal" explanations of phenomena and related assertions (Miles & Huberman, 1994). Validity claims were further supported through the use of flexible observation schedules and non-subjective language in the writing of observations/field notes and use of bracketing for researcher opinions/ideas (Carspecken, 1996).

Methodological Limitations

A major limitation of the methodology is that the position of the researcher may have biased interaction with the data sources. As a female who has struggled with mathematical aspects of science education, I have some insider perspective on way students can become disconnected to the content of a course. This sense definitely fostered my promotion of meaningfully relevant topics and experiences for students. On the other hand, I have coursework equivalent to a Master's degree in geology and am clearly unlike the undergraduate females who choose non-science fields of study. Through the use of member checking I was able to filter out my assumptions of what students needed and why in order to listen to and make sense of their issues of learning within the courses. In addition, including my other research projects, I have interviewed forty undergraduates about their experiences in Collaborative courses. As a result, I have expertise in speaking to them and assessing and representing their thoughts and ideas.

My position as a doctoral student conducting research on professors may also have limited the study. Power relationships exist in higher education and I would, at times, keep silent about topics or issues that were integral to my study. As a student, I felt committed to the needs of the students in the courses and may have been unable to fully understand the reasons for professor action in certain situations. I attempted to minimize these constraints by supporting communication between all parties, that is, supporting the professors collection of data directly from students and urging students to talk to professors personally about their issues an concerns.

Chapter Overview

In the subsequent chapters, I present the descriptions, findings, analyses, interpretations and conclusions of my research. In Chapter Four, I present an in-depth description of the context of the research study using teacher centered reform model by Gess-Newsome et al. (2001). In Chapter Five, I describe the assisted action research projects and interweave some analyses as it emerged during that portion of the research. In Chapter Six, after characterizing the nature of the assisted action research projects I describe the practical theories that informed the professors' practice and consider inclusive practices. My concluding Chapter Seven, revisits the context of the setting to make sense of the professors' interest and stance toward issues of an inclusive pedagogy and asserts necessary conditions of the teacher change process.

CHAPTER 4

CONTEXT OF THE RESEARCH STUDY

Introduction

Chapter 4 describes the context of my research study. In this chapter, I introduce the participants, describe their courses, and represent their settings. I attempt to summarize the multiple factors acting on their teaching efforts in order to situate the participants in their settings as holistically as possible. Because I find the teaching as a way of being perspective particularly valuable this effort was very important to me. It allows me in the next chapter to present my evolving understanding of the professors' situations and how this study, though potentially transformative for their practice, struggled to bridge the gap between theory and practice for many intriguing and mundane reasons.

Chapter 4 is organized to introduce the reader to the context, raise questions, and set the stage for Chapter 5, The Assisted Action Research Projects, where I answer my first research question; How does the research design, namely, placing the professor in a position to conduct an assisted action research project, help to illuminate and promote the conditions necessary for teacher change toward adoption of an inclusive pedagogy? Following this introduction, I introduce the participants and courses under investigation. Next, I take a deeper look at the context of the participants and their settings by describing and representing their lived experience (van Manen, 1990) through the categories organized in the Gess-Newsome et al. (2001) teacher-centered reform model. Interwoven into my descriptions are "fictionalized" narrative accounts that attempt to capture the essence of the professors' everyday situations. Finally, I close with a summary that highlights the major themes from the representations using cross-case analyses that offer meanings to the actions described in Chapter 5.

Context of the Research Study: Participants and Settings

In this section I describe the participants and their settings. First, I briefly describe the courses that each professor was developing and teaching. Following that I represent the participants and their settings using a framework from the Teacher Centered Reform Model (See Figure 2) proposed by Gess-Newsome et al. (2001). The reader will notice that I tend to present information about Dr. Willis before Dr. Gibson. This is because I believe I came to better understand the context of Dr. Gibson's setting and, when writing, didn't want her "story" to overshadow the work done with Dr. Willis. Because I feel that I am more like Dr. Gibson (we are both female, white, mothers, wives, educators) and I had more contact with her during the project, I feel my understanding of her setting is more complete than it is for Dr. Willis'.

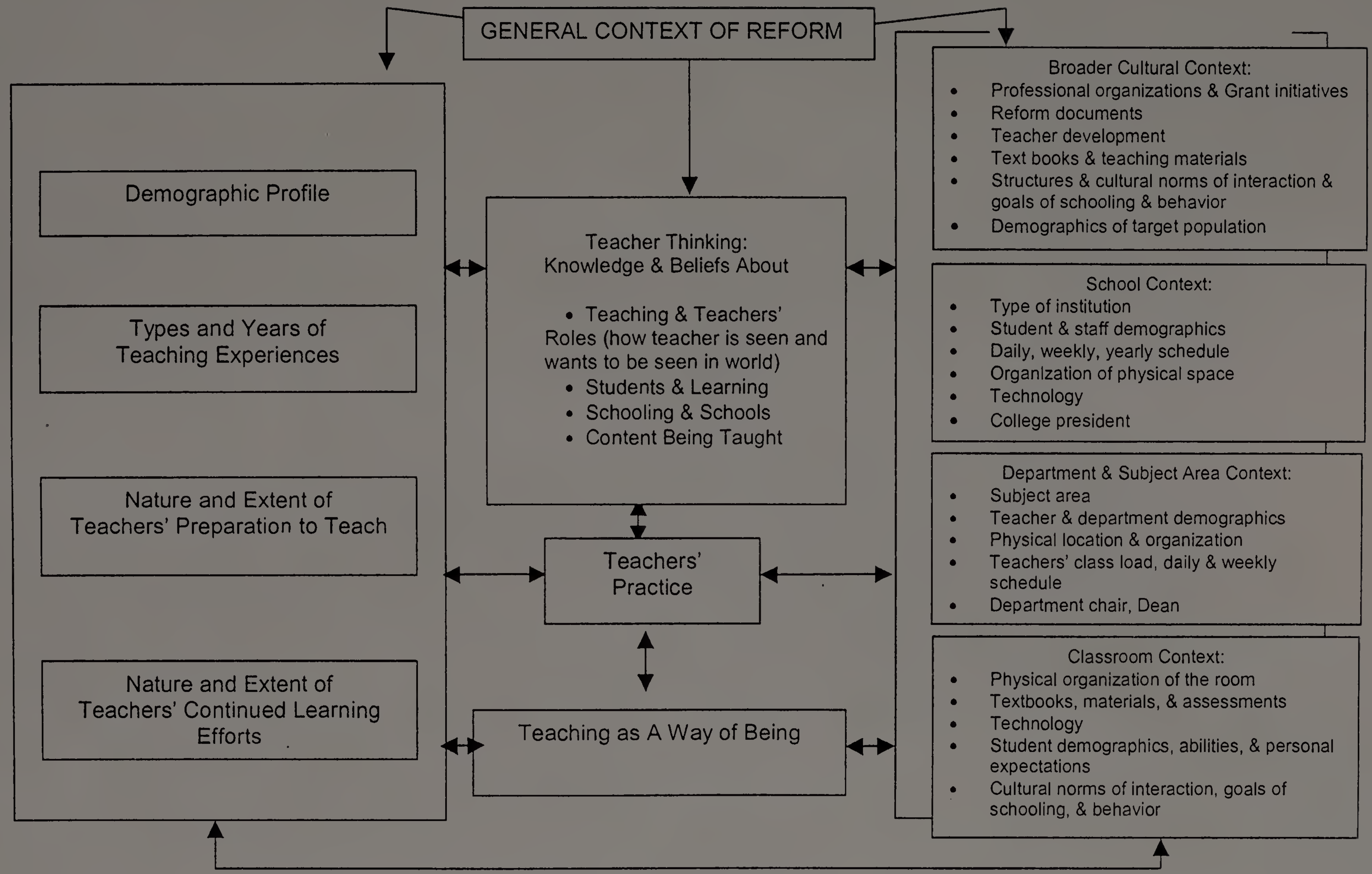
Setting: Introduction to the Earth's Oceans

Dr. Jim Willis is the instructor of a popular undergraduate general education course called Introduction to the Earth's Oceans. The course has met nonscience majors' general education requirement for the physical sciences for 15 years and carries a student load of over 600 students each semester. The course is taught in two sections. Six professors share the responsibility for the course by taking turns teaching it each semester. Two teaching assistants are assigned to the course each semester.

The semester I conducted this research was Dr. Willis' first time teaching to nonscience majors in an introductory level course. Dr. Willis is an assistant professor in the geology department and had been on the university faculty for almost three years. He expressed interest in my research in this course because he felt that "there are questions I'll probably have about how it's going for the students and what I could do better" (introductory meeting). He liked the idea that I would be able to research his questions, provide summaries of my findings, and discuss issues of teaching and learning with him. He found the goals of teaching equitably worthwhile yet challenging and hoped to learn more about how to teach using inclusive strategies. Below are excerpts from the website that help to describe the course.

> **Congratulations.** You are enrolled in a general-education course designed to acquaint you with the 71% of our home planet covered by water. The ocean is still a region

Figure 2 The Teacher-Centered Systemic Reform Model: A College Classroom



shrouded in mystery, where new discoveries are being made almost everyday. Our goal is to provide you with a working knowledge of how the oceans work, how they impact and control climate and the habitability of our planet, and how they affect our very existence. These are broad themes, but as citizens of our small planet, we would argue that everyone should take a course like this! With jet service to almost anywhere in the world, financial markets electronically and politically linked for "real time" transactions 24 hours a day, and global populations striving to live as well (and as wastefully) as we do, it's important for all of us to gain a holistic view of our physical world. At the same time, we want you to understand the notion of scientific thinking and analysis, how researchers collect data, form ideas, and then test those ideas. We want you to understand the basis upon which we have developed many scientific theories. For example, hurricane frequency is likely to increase in coming years. Why? The Labrador Current moving south along the New England coast is warmer now than it has been in 70 years. Why? Will this impact the price of fish in the grocery store? The oceans will play an important role in climatic change in coming centuries. How? Scientific research can have a direct effect on public policy and spill into your everyday lives.

Class Meetings: Our class meetings will be interactive. Although traditional lectures will be used to convey the basic information necessary to understand the topic being addressed, some of your time in class will be discussing issues, doing exercises, and interpreting data so you can learn by doing. Your participation is crucial and your attendance is mandatory.

Classes are 75 minutes long and we will need all of that time to consider the subject of the day. Please be prompt. If you are unavoidably delayed, please use the back entrances to the auditorium. Courtesy during class is important. Please pay attention to what we are doing. Come to class prepared to engage in the material. Please, do not begin getting ready to leave (closing notebooks, putting on coats, etc.) until the class period is over.

1. Lectures and Readings - The reading assignments in the textbook and in the "interactive guide" are designed to complement (not replace) the lecture material. In order to do well in this course, you are expected to attend all lectures, take good notes, actively participate in the in-class exercises and discussion, and read the assigned material. It is best to read assigned material before class. The exams will be based both on the material presented in class (including videos and in-class exercises, see #2 and #6 below) and on the assigned readings.

2. Films and videos - there will be several good films and videos during the semester. You will be responsible for the material covered in these films.

3. Examinations - FOUR EXAMS will be given during the semester (see attached schedule). The exams will account for a total of 60% of your grade in the course. The lowest score will be dropped from your average. The exams will consist of multiple choice questions, some of which will pertain to diagrams or illustrations that we have discussed in class. All exams will be administered as "pyramid exams". You will have a set period of time to take the exam, turn in your answers, then retake the exam with open book, open notes, and open discussion among people in the class (graded 75% for the "solo" effort and 25% for the "group" effort). Please note: THERE WILL BE NO MAKE-UP EXAMS.

4. Final Examination - The FINAL EXAM will cover the last segment of the course plus additional questions from previous material; i.e., the Final Exam is cumulative and will be

worth 20% of your grade in the course. The date, time, and place of the Final Exam will be announced later in the semester. Please note: EVERYONE MUST TAKE THE FINAL EXAM.

5. Help sessions - Help sessions will be offered before each exam. The time and location of each help session will be announced in class (usually the evening before the exam). Professor Willis and the T.A.s will also hold individual Office Hours (please utilize these resources!).

6. In-Class Exercises and Take-Home Assignments - Throughout the semester, problem solving exercises and follow-up classroom discussions will serve as important components of our active learning environment. You must be in class to participate and benefit from these exercises and discussions. All of the exercises will be collected upon completion; there will be no make-ups and no papers will be accepted after that class has ended. The concepts covered in these in-class exercises will be included on the exams. The exercises collectively will be worth 20% of your grade. Each exercise will be checked and assigned either 1 or 2 points. Full credit for each exercise will be earned by successful completion of all requested information.

7. Final grades - Your grade will be computed by averaging the highest 3 of the first 4 exams (60%), and adding this to the Final Exam (20%) and the in-class exercises (20%).

Beginning in 1997, two participating Collaborative professors in Dr. Willis' department began revising the course. The professors sought to introduce more elements of inquiry-based learning into the setting. The changes included (a) paring down the lecture from the whole period to 45 minutes, (b) adding a 30 minute cooperative group work exercise out of a professor authored workbook, (c) adopting the 2-stage exam structure whereby students take the exam solely first, then with a cooperative group, and (d) implementing an on-line immediate feedback homework program (OWL – On-line Web-based Learning). The other professors teaching the course adopted the changes as they occurred with some personal modifications based on individual interests. I learned about Dr. Willis' prospective interest in my study through one of the Collaborative professors who initiated the course changes.

My data collection about the course spanned eight months (See Appendix G). During that time I engaged Dr. Willis in two ninety-minute semi-structured interviews (at the beginning and end of the semester), three thirty-minute conversational meetings, two twenty- minute phone calls, and four brief informal conversations following his class. I conducted twenty-three classroom observations. In addition, I conducted fourteen forty-five minute semi-structured interviews with students (ten females, four males) at the beginning of the semester and three forty-five minute focus groups (with three-four students each) and three individual interviews at the end of the semester.

Setting: Introductory Genetics Course

Dr. Mary Gibson is the developer of a new undergraduate general education course called Introductory Genetics. She is a tenured full professor in the biology department and has been on the university faculty for twenty years. Dr. Gibson welcomed my research into her teaching and course design because of her interest in improving teaching and increasing the interest of all students in science. Below are excerpts from the course website that offer a glimpse into her goals and purposes for teaching the course.

> What is the Introductory Genetics Class About?
>
> As we enter the era of the human genome, we will encounter a rapidly increasing number of issues involving biotechnology, and each of us will make important choices in life based on DNA science. Are you ready?
>
> The Introductory Genetics team's goal is to give you the information you need to understand DNA technology and research. **We strive to take the jargon out of science** to make each lesson clear. Our on-line Discovery Modules will introduce you to the science of DNA by guiding you through the use of virtual lab equipment. Understanding the technology of DNA research will allow you to make informed decisions about contemporary **personal, political, and ethical choices facing society**.
>
> The Introductory Genetics class is **topic-driven**, meaning you learn about many different aspects of DNA as we discuss **issues that are important to you**. What will the **Human Genome Project** mean for you personally? Would you like to learn **how** DNA evidence has **proven the innocence** of "convicted felons", saving wrongly convicted people from the death penalty? Have you wondered what's so important about **stem cell research**? Learn about cloning, cancer, gene therapy, genetically modified foods, and more.
>
> The Introductory Genetics class is targeted at participants who **do not have a science background**. One method we employ in teaching the science required is **interactive, online** Discovery Modules that **walk you through the basics of DNA science**. We are emphasizing the importance of classroom interaction and participation and have developed a public forum to ask questions and share more information about topics discussed in class. (Introductory Genetics course web pages)

The course covers, in general, six major concepts related to DNA; human cloning, stem cell research, the human genome project, decoding genes, DNA forensics, and the beginning of life. Classes meet twice a week for an hour and fifteen minutes each. Class is generally run as an interactive lecture with the instructor using a Powerpoint presentation accompanied at times by short video clips. One laboratory exercise is offered during which students isolate a sample of their own DNA. They take a “field trip” to a DNA sequencing laboratory on campus. At the end of the semester, a number of class periods are devoted to peer teaching as students present self-selected projects to the class.

Students are required to attend all lectures, complete all reading assignments, take weekly on-line preparation quizzes known as OWL (online web-based learning), and participate in class. Grades on are based on three exams, (20% each), a final DNA Project (20%), in-class quizzes (10%), and the OWL quizzes (10%).

The course web site lists two instructors, Dr. Mary Gibson and Dr. Liza Richards. Dr. Richards has co-developed the course with Dr. Gibson. A former doctoral student and post-doctoral student from in the department she now focuses on creating computer simulations and tutorials about DNA and molecules. For the course, she instructs students on a number of topics but her primary responsibilities consist of the computer technology enhancement of the course. In general, she consults with instructors at the university and elsewhere to develop science tutorials to enhance the teaching and learning of molecular biology. She also builds websites and has created an impressive site for the class and another on the topic of DNA in general. Students in the class access much of the information they need for the course (assignments, announcements, online materials and quizzes) off of the website she oversees. Consequently, students must have on-line capabilities. Their learning is also augmented by the course text. Dr. Gibson and Dr. Richards are in the process of authoring their own text for the course.

I became involved with the Introductory Genetics project after meeting Dr. Richards. She had attended a workshop I co-presented on Gender Issues in Science and Mathematics Education and spoke to me following our presentation. I told her of my research interests and she immediately invited me to meet Dr. Gibson and consider conducting research in the course. At the outset, Dr. Richards expressed her interest and commitment to designing a course that was “female-friendly” and inclusive to all types of learners. She was very excited at the prospect of having me assist them in their understandings of how to design/teach the course. The idea of the assisted action research methodology was of particular interest to her, and subsequently to

Dr. Gibson. The idea that someone else (me) would investigate their questions about the course was very appealing.

I began my data collection about the Introductory Genetics course in October of 2001 (Appendix H). Throughout the fall, Dr. Gibson was organizing her team of support and had scheduled monthly meetings to discuss course development. It is important to note that the team was teaching the course for the first time that fall to a group of eighty senior citizens. Much of the team meetings were spent discussing how the present course could be adapted for undergraduates.

Five team members engaged in these discussions along with Dr. Gibson and Dr. Richards. Paula and Hans were two of Dr. Gibson's doctoral students and Ramya was a senior biology major. Hans and Ramya were hired as teaching assistants and Paula acted as a general assistant, dealing with paperwork issues, offering advice on content issues, quizzes, and grading, and teaching the one laboratory experience. Two other support personnel were involved whom I never met; Jane, a doctoral student in Dr. Gibson's lab was responsible for posting the Powerpoint lectures on the course web pages and Chang, a doctoral student in animal science, was creating a glossary of terms for the web pages. Ramya received graduation credit for her work while all the other students were funded at a variety of levels from a variety of sources (work-study funding, teaching and research grants).

My interaction with the course was intense and varied. I attended four team meetings about the course and observed sixteen classes. I conducted two formal interviews (1 to 2 hours each) with each instructor (beginning and end of the semester), met jointly with the instructors about the assisted action research project four times (1-1.5 hours each), emailed six summaries of data collection findings and questions to the instructors, and reviewed course documents. Early in the semester I conducted forty-five minute semi-structured interviews with six female and three male students. I interacted with these students two or three times via email throughout the course and conducted two focus groups (three students each) and three individual interviews at the end of the semester. In addition, I participated in the course development in ways I had not intended. Early on I was asked to write a mini-research summary for the course that was added to a potential Davis grant funding request. Two months after the course ended, I joined the instructors, Paula, and Dr. Gibson's sister at a planning meeting and subsequent workshop for a females-in-science summer camp held at a preparatory college in our region. And though I couldn't attend, Dr. Gibson invited me to join them in New Hampshire when they taught an Elderhostel class in the fall of 2002. Finally, Dr. Gibson has repeatedly invited me to remain a part of the course development in the upcoming year. The culmination of all these intense and exciting collaborations allows me to make representations about Dr. Gibson, the Introductory Genetics team, and the development of the course. I further explore the context of Dr. Gibson's situation later in this chapter.

Context of the Research Project: A Deeper Look

In this section, I describe the participants and delve deeply into the settings of their work and, where possible, their lives. The following quotes attempt to introduce the professors through their own voice and portray something about how they perceive the course they teach.

> It's really the same thing that I want even my upper division students to come away with, except a little bit more basic level. And that's to have a fundamental understanding of how the whole fluid Earth system works. At the end of the semester, I think everybody who is a college graduate should know how big the Earth is, where it is in the solar system, what it's made out of, our orbit around the sun, what causes the seasons…[and] basic things about maps; latitude and longitude, size. I always stress students ending up with an intuitive feeling for scale. The ocean, of course, climate and climate change. Environmental issues on a global scale some people would argue are really being dominated by the oceans. Water has this huge amount of thermal inertia, it most of our population lives within a few tenths of meters of sea level, it controls our weather, it's going to be a buffer in climate change, it's either going to slow things down or maybe we'll actually make changes accelerate. So it's important that we have some kind of basic understanding of the oceans. But you know [Introduction to the Earth's Oceans] in a way, for a course that I'm going to teach is, it's an easy sell because I think it's easy for people to be kind of into the ocean and it will get them into a science class where they learn some really basic science… a lot of the students will actually get to see where scientific data come from and how you can actually look at that information yourself to come to some or your own conclusions about the way something works. And I think, even maybe for the freshmen just coming into college, it should give them some confidence later on in their college career so that they can actually look at something abstract as a series of numbers that represent something like temperature or salinity with depth and actually be able to say something about the conditions of the oceans at that location or how the ocean is actually working. And that should make them feel pretty good about themselves.
> Dr. Jim Willis, Introduction to the Earth's Oceans course instructor

> I think the part of it we're going to make applicable [is] by giving them the information [about DNA] so they understand that there's already things out there that they can make connections with - only they didn't realize it. I think that it's really true that knowledge is power and in that little bit of information they'll be able to understand a lot more about what they hear in the world around them and they'll begin to pay more attention to, for instance, if there's a debate on an issue or a topic that's important to them.
> Dr. Mary Gibson, Introductory Genetics course instructor

What meaning can I make from these expressions of hope? How can I interpret and illustrate the multiple and complex components that support and constrain action toward the goals reflected in the instructors' comments? In this chapter, I consummate the challenging task of representing the professors' "lived experience". I use the term *lived experience* following van Manen's (1990) explanation of phenomenological representation, that is, that our particular sociocultural and historical lenses shape our meaning making. The lived experience is the aggregation of the meaning that we subjectively connect to particular situations (Taylor, 2002). To represent my subjective understanding, I use a myriad of qualitative reporting methods. Where useful, I make use of descriptive narratives. Where pragmatically necessary, I use rich description. My goal for this chapter is to set the stage for the next in order to represent, as Taylor (2002) so effectively describes "something significant about the ineffable quality (or *essence*...) of the relationship between good teaching and learning" (p. 19).

The use of narrative as a form of interpretive reporting is making a gradual appearance in the education research base (Clandinin & Connelly, 1994; Richardson, 1994; Van Maanen, 1988). I use it here to represent aspects of the participants' experiences as teachers and beings in the world (Feldman, 1997). I like using descriptive narratives because they attempt to avoid, as Taylor (2002) states, "rationalistic" description and its supposed "value neutrality and unfeeling objectivity" (p. 20). Such avoidance is possible by including in the narratives the "emotional interplay between the participants, most notable between the researcher and the researched" (p. 21). Consequently, interwoven into the narratives is my personal experience in the setting and glimpses of the researcher-participant developing relationships.

I believe narrative accounts afford the reader (and myself) a deeper and more holistic sense of the "web-like structures that extend not only through time and space, but also across human relations" (Feldman, 2002, in press) that constitute the teachers' situations. Mattson

(2002) argues that narratives allow for "condensed description… where events that are thematically related but separated in time and space… can be 'crystallized' into a single entry" (p. 264). The use of narrative accounts also reflects a feminist methodology in that they represent an interactional approach (Fehr, 2002) to understanding the whole versus the use of traditional reductionist techniques. Such accounts represent understanding of the emotion and relationships that developed between the participants and me. As an educational researcher acting as knowledgeable other and critical friend in this study, emotion and relationships played a key role in determining my purposes and interactions throughout the study. Narrative accounts, as fictionalized vignettes, allow more literary freedom and personal expression to illustrate the affective domain and its myriad of interactions.

Mattson (2002) proposes that narratives "[engage] readers on an affective level" – a level not often explicitly realized when using more traditional forms of representation. Taylor writes, aided by the work of Van Maanen (1988, 1995)[1], that narrative accounts, or *impressionistic tales* can act to bring together the writer and reader by creating engaging stories that allow the reader to "relive the experience from beginning to end [and] to work out its puzzles and problems" (2002, p. 24). These stories magnify the participants' experience making it striking and memorable. Mattson (2002) describes this in reference to the positionality of the reader, that is, that the reader is given an opportunity to consider themselves in relation to the text and it can act as a "springboard" for reflection. In contrast, traditional text positions readers on the more passive "receiving end" (p. 265).

Taylor (2002) states, in reference to literary standards, that the narrative stories' plausibility or believability is more consequential than their full accuracy. My aim in the following narrative accounts was not to take a picture of the setting through words, but like Taylor, to create an image from a certain perspective. The perspective that developed, with respect to the research situations, was one of respect, admiration, puzzlement, and at times frustration. It was framed by my pre-existing experiences and biases as a white female who studied science and

[1] John van Maanen's recent works focus on representation in ethnography. He explores nonrealist genres of representing ethnographic studies where the focus rests on the fieldwork conducted. He also uses Impressionist art styles to reveal how *tales of the field* can effectively represent the lived experience of the researcher and participants.

became an educator. This emotional perspective is valid and guided much of our interaction and decision-making. It is the result of hours of discussion, observations of teaching, and written reflection. It is an accumulation of what I have learned and believe about these situations after, in Mary's case, a year of researching her aims, motives, and behavior as she strives to create a new course. The narratives used in her case are story-like and exemplify the storied way she lectures and describes her situation. With respect to Dr. Jim Willis' setting, the narrative is less personal and reflects more the way he mused about his situation. Descriptions of his setting also tend to rely on more traditional modes of representation. This is because the "emotional interplay between participants, most notably between the researcher and researched" (Taylor, 2002, p. 21) did not develop as deeply as it did with Mary. The constraint of time created briefer and less frequent meetings and interviews that led to my belief that he needed to focus more on the immediate responsibilities of his work than my research questions and issues. The dynamic of that situation is best represented through quotes, descriptions and field notes. Themes that emerged in both Mary's and Jim' settings are represented in condensed form in the chosen representational accounts. In addition, both Jim and Mary reviewed the narratives, agreeing with their accounts, perspectives, and expressions.

I supplement the narratives with more traditional interpretive modes of reporting through the use of "thick description" (Geertz, 1983) that "present[s] details, emotions, and textures of social relationships" (Rossman & Rallis, 1998). Such accounting is framed using the Gess-Newsome et al. (2001) Teacher-Centered Systemic Reform Model (TCSRM) for the college classroom. Their model is used to help frame the multiple components influencing the instructors' thinking and behavior. The "model simultaneously recognizes the influence and interaction of the teaching context (both structural and cultural), teacher personal characteristics, and teacher thinking as a means to understand classroom practices that change (or fail to change) as a result of reform initiatives" (p. 4). I have added, however, an integral piece to the model - the teaching as a way of being perspective offered by Feldman (1997) and Stengel (1996), and by implication Helms (1996). I have enhanced the model with this perspective because it forces us to consider the nature and extent of how teachers want to be and be seen in the world – and how teaching fits into their way of life. The use of narrative accounts symbolize my effort to represent the ways of being perspective. Further portrayals of the ways of being perspective are illustrated in the next chapters. Both representational modes presented here, narrative accounts and thick description, allow for the "thick interpretation" (Denzin, 1989; Rossman & Rallis, 1998) offered in chapters five and six.

Integral to the interpretive claims and assertions presented in this paper is "thick" understanding of the contexts that exist and developed during the project. I draw on the representations of the professors' lived experience to make meaning of the actions taken or considered during the assisted action research projects. My organization for presenting these ideas mimics as best I can, how I thought about my research during the data collection phases. In Phase I, as passive observer, I observed classes, recorded notes, interviewed students and professors, and reviewed course documents. In Phase II, my role became more active and, as knowledgeable other and critical friend, the professors and I initiated the assisted action research project. During that phase, as I considered its process and activity, I constantly referred back to my assumptions from Phase I, searching for meaning as the participants and I struggled to find good questions to explore and actions to take. Thus, I found connections between what was happening in Phase II with what I surmised about the context from Phase I. It is the exploration of those connections that guide me to my final conclusions of this project and support my belief that action in the classroom is pragmatic and at times very adventitious.

Within the settings, I describe the personal factors (demographic profile, types and years of teaching experiences, nature and extent of teachers' preparation to teach and continued learning efforts), contextual factors (broad cultural context, department context, classroom context) and teacher thinking (knowledge about teaching and teachers, students and learning, schools, and the content being taught). The first section of the chapter focuses on Dr. Willis' setting and the second on Dr. Gibson's. The summary section uses cross-case display tables to highlight salient themes and issues.

Section 1: Dr. Jim Willis

Personal Context

I first met Dr. Willis in his office two months before he was to begin teaching Introduction to the Earth's Oceans. Nonscience majors regularly complain about the science building that houses his office, it's "too big", "too confusing", and "too far from everything". I however knew exactly where to go. I had spent many years working and learning in those halls having roamed them years before as a geology major. Some of the professors I had had as a student were still on the faculty and the feel and look of the place were very familiar. As I knocked on Dr. Willis' office door I remembered all the times I had visited that office in the past to ask questions of my paleontology professor. Dr. Willis greeted me warmly from behind his desk. He was finishing up a meeting with a graduate student, "Okay Tim, let's meet on this tomorrow then. I'll be in later too if you need to check back."

We talked for a half-hour. He had agreed to participate in my project over the phone two weeks earlier and at this meeting I reiterated why I hoped he would/could participate. I explained my love of geology, past work in the introductory course, and interest in having a participant from the department in my study. He was open to my questions and interested in my work. Dr. Willis, Jim, explained briefly about his time commitments for the spring and that he would be busy but was interested in helping me out and learning about his teaching. We couldn't talk long, he had another meeting, but we would meet again for an hour-long interview so that I could learn more about him. At the time I didn't really understand his time commitments or their associated stressors – I had never researched a junior faculty member before.

Demographics

Dr. Jim Willis was raised in eastern Massachusetts. When asked how he became interested in geology he attributed it to hours spent at his local library poring over books about rocks and volcanoes, "and I remember looking at all these diagrams, mainly of plate tectonics and subducting plates and I just thought it was so cool…I can remember just poring over those books." He describes how his love of learning can be traced to his family and explains how, especially on his mother's side of the family, there was a huge emphasis on education. His mother, a first generation American, was a teacher and her siblings all finished their college years with advanced science degrees. Jim's brother, a geotechnical engineer, had a major influence on his undergraduate decision-making to study geology. Jim headed out west to climb and study rocks at a large western university nestled in the Rocky Mountains.

After completing his undergraduate degree, Jim took time off from school. He traveled in Europe and reveled in its mountains and opportunities for challenging rock climbs. His undergraduate college town became home between adventures. On one occasion he met up with a past geology professor and asked about his projects. This professor had a pivotal impact on Jim's life. With grant funding available, the professor suggested that Jim start on a master's degree and set his academic focus. This professor became his advisor, professional colleague, and long-time friend. He introduced Jim to "climate modeling to try to understand how the environments of the geologic past... actually worked. And I thought that was just the coolest thing".

At that point Jim became heavily involved in computer modeling of climate systems to understand global climate change of the past, present, and future. After completing his master's degree he wanted to continue the work and was awarded an NSF grant to conduct doctoral research with a nationally known center for oceanographic and atmospheric research in conjunction with his university. After completing his doctorate, he began a post doc at the same university and within a short time was offered a staff scientist position at the research center. Soon after accepting the staff position, he learned of the academic opening at his current university. A year later, he joined his current colleagues as an assistant professor. Looking back, he's glad he made the change back to academia, "I realized that I didn't want to be in a research lab... I didn't want to spend my career just doing research... [it's] not nearly as fun as being on campus."

Jim moved back east for his professorship with his wife Pam and son Peter. They bought a house within a few miles of campus and Peter is close to his elementary school where he attends the fifth grade. Pam is a graduate student at the university in the fine arts program. The two share childcare responsibilities as much as Jim's workload allows. In summer, for example, Jim may work at home in the mornings to be near Peter while Pam works at the university and in the afternoons they switch. Jim has less time to rock climb these days but he still enjoys the outdoors with his family. His home is situated at the base of a small volcanic range and after work he grabs a trail run when possible.

Types and Years of Teaching Experience, Preparation to Teach, Continued Learning Efforts

When Jim described his research scientist position he stated,

> I had this position, this good job [in a town we loved], I was at the research center working with oceanographers... and I was teaching one course ... so I still had some contact with students – I had a really good thing going.

Here we see how teaching and working with students, even as a peripheral part of his past research scientist responsibilities, was very important to Jim. He had assisted with geology courses while in graduate school and taught a course while at the research center. As a university professor he has only been teaching for a few years and still greatly values his contact with students.

> I have a real open door policy in terms of the office...and I would go all week long with someone just knocking on the door and coming in and saying, "Jim, I need your help with this" or "that" and that's great I love that... I will never turn anybody away.

Most of Jim's teaching experience has been with science majors and graduate students in his discipline. He has taught, on average three courses per year at the university, "maybe with a seminar thrown in". For example, he developed and teaches an upper division course that focuses on many of the same topics embedded in the introductory level course talked about in this paper. His classes often include labs and Jim and the students spend a lot of time working together in small groups grappling over problems and data that emerge from their computer models. Prior to this study he had never been involved in a project that focused on teaching.

Academic Context

Cultural Context/Departmental Context

> They brought me out for an interview and I came out... and met everybody in the department and just really [enjoyed] the people more than anything – and thought these guys are great. And I ended up, one thing led to another, and they made me an offer and I actually, I'm really glad that I ended up coming...

Jim's department is small (See Table 7 in Appendix I). It has thirty faculty members, seventy-six undergraduates, and sixty-one graduate students. There are no people of color on the six female and twenty-four male faculty. The department is mostly white, non-Hispanic. The department has an equal number of undergraduate males and females while almost two-thirds of the graduate students are male.

I have discussed aspects of the Earth Science department with Jim and three other faculty members as part of this and other small research studies. Although I never explicitly asked them to describe the culture of the department I believe that, based on my work, they have provided some valid insights. Excluding Jim, the other faculty members (one female, two male) I have spoken to are all tenured professors who have worked in the department for over 15 years. All four professors consider the department open, friendly, and supportive of both faculty and students. An example of this comes from Sally who describes how when she, as a single mother, had an infant her graduate students and colleagues were very supportive. They approved of her bringing a crib into the lab and lightened her teaching load that first year. She also said that because many professors had young children at that time there was an unspoken understanding of parenting issues and leniency regarding research hours and teaching to allow parents to provide childcare. Ed, another professor, agreed. He feels that the department has always supported faculty as they have struggled to negotiate family needs with academic responsibilities. His colleague, Martin, however, points out that mood of the department is often hinged on the goals of the department head and dean of the college. He describes how, because the two are presently focused on research and the awarding of grants, individual initiatives focused on improved teaching and learning are not fully supported. Ed echoed that in his statement, "Others think I spend way too much time on my teaching but I don't care." One individual felt that those professors focusing on their teaching would likely be passed over for more administrative appointments.

Jim, as a junior faculty member, is in a tricky situation when it comes to characterizing the department's culture. He needs the approval of his committee during an up-coming mid-tenure review. He also has not been in the department very long. Plus, a departmental emphasis on research fits his current focus as he sets up a new lab and writes articles for publication in scientific journals. In that regard, he is not overly frustrated with implicit expectations to conduct research and publish. Yet, the message about teaching is not lost on him: he states that future course development will have to occur "on my own time." He is confident that he will find the time to develop more than just his own courses. He believes that the department is open and supportive of his ideas, as evidenced by his statement, "somebody should be doing a high numbered high-powered global change course... I'm going to talk to the instructor that teaches global change about making that course lower level."

Classroom Context

I begin this section with two narratives about a day in the Introduction to the Earth's Oceans class. First, following a quote, I personalize Jim's experience teaching this class as a way to represent the emotion and everyday challenge of teaching this course. The narrative is derived from my observations of the class, comments Jim made to me before and after class, and interviews with him and his students. I try to convey in this account the tension that exists in this setting on many levels, professor/student interaction, student passivity/student participation, professor speaking/students reflecting, and professor responsibility/structural and organizational constraints.

The narrative account of my experience in the same class is offered next. Most of this account comes directly from my field notes from that day's observation. I embellish those thoughts with my knowledge of how the students view lecture, how Jim feels about lecturing to three-hundred students, and what I consider possible in this learning environment. In this narrative, I convey the constant critical perspective I held during the research. I am not asserting that this is necessarily a good thing. There were many times that I wished I didn't hold such high expectations of the teaching I observed. As I learned, my teaching and learning objectives, though shared by the professors, were naïve and often unattainable for a myriad of complex reasons.

A Day in Introduction to the Earth's Oceans: A narrative of Jim's reflection

...the thing that I don't like about [the way we run the course] is the disconnect between me and [the students]. (Jim, final interview)

I can't believe I'm going to be late for class. I agree with need to learn about harassment policies here, but I have classes to teach! And 300 students waiting! I race across campus and arrive in class 4 minutes late, the students are talking happily, they probably don't mind that I was late... I apologize. Alright, here we go, the train begins, two lectures in a row, 1 hour and 15 minutes, to two sections of 300 plus students each, is this nuts? I busily get the projector set up and my laptop ready, one student worriedly asks about the exam, I smile at him, "I'll talk about that now." I adjust the lights and ready the screen.

11:25 am

I start class with announcements about the last exam. "You did really well," I say, "the average was in the mid 80s. Your grades will be posted online and on the bulletin board in the science building. Today we are going to wrap up what we did last time - it was a nice day that day, if you missed class be sure you get the notes from someone."

We start by reviewing the slides about waves, shallow versus deep water. I remind the students that they'll need to understand the difference for the next exam. I show a diagram with the shallow water wave equation.

"What is L?" I ask.

Some students respond, "Length."

"Right, wavelength," I answer. "You'll see at the end of class why we care, there is a reason." I wonder if they do see the reason, and how to get them more involved in all of this. The students in the back are starting to talk again. Another crazy aspect of teaching this course, what to do with these chatty and sometimes rude students. I continue with the presentation about waves.

"Where does a deep water wave become a shallow water wave officially?" No answers from students, I explain. I then explain how if you surf in New England you know the best waves are in the fall because that's hurricane season and surfers will drive to Rhode Island to get the early waves with the longest wavelength. The students listen quietly.

12:00 pm

We complete the slides on waves and students begin a cooperative group activity out of their workbooks. Students immediately get to work and the place erupts with noise. I hang out in front and answer questions. It's a good activity, although it doesn't exactly jive with what I want them to focus on. I need to coordinate the activities better with the lecture. The students are practicing using the wave speed equations and considering what their numbers mean, I hope... are they getting it or just copying? And then there are the students who sneak in just for the activity portion of class...

12:17 pm

The students seem to have completed the activity. I put up the slides of tsunamis that I pulled off the web. Very cool dramatic pictures of the effects of these shallow water waves as they reach land, this should bring the importance of the lesson home for them. The students are antsy and starting to talk more.

“Just listen for 5 more minutes!” I tell them. I show them diagrams of the water depth and wavelength of tsunami waves in the open ocean that leads to an understanding of their speed.

“So what! Why did we do all this stuff in your notebooks? It was to sort this out, this is the reason we care, tsunami waves are shallow water waves!” I tell them.

We figure out the speed of the tsunami wave, it can travel at 200 meters per second, that’s four hundred and forty miles per hour! I finish up but by now the students in the front are my only audience. It’s time to go. Did they get the point? I am so removed from them in this lecture hall it’s hard to know. This is so different from my other classes, I am so different in here. It feels odd. Well, time to reset everything for the next class, they are already filing in.

A Day in Introduction to the Earth’s Oceans: Tarin’s reflection

Where is Jim? He’s not usually late like this – hard to tell the students you need to start on time and be late yourself!? Well, the students are fine with it – talking away and waiting. Jim arrives almost 5 minutes late, turns out he had a meeting he had to escape from. A tough way to start the day’s teaching. I remember him telling me that he tries to spend every minute of the morning before he teaches getting his lectures ready – guess he couldn’t do that today...

He arrives looking a bit frazzled, he doesn’t look at the students and appears, as he does more and more lately, very serious. He brightens up when a student comes up and asks him a question, but when dealing with the whole class he seems detached. This huge lecture scenario is taking its toll on him I think, it’s not going how he’d like it to. Can’t his teaching assistant help him out more somehow? Those guys just sort of hang out. I’ve had students tell me they didn’t even know who the teaching assistant was let alone that they were there to help. Why isn’t anyone asking for help around here? No one seems very good at that.

He begins class with information on the last exam. It’s good the students did pretty well – they were confused about how they did on the first exam, but since then Jim made the exams more straightforward. I always wonder though with multiple choice exams like this – what is the big “take home” message and are they getting it? And, how is this information being used in the world, who benefits? Who doesn’t? Again it’s about relevance and reasons why the information exists... I believe the learning should focus more on these areas.

Jim begins his lecture with a review of past information about waves. Some of the students I’ve interviewed really appreciate this, some think it’s boring. But they all say it helps them study for exams and that makes them feel it’s worthwhile. Jim also is waiting longer to change slides and putting less information on the slides, this is really helpful to the students. Early on they could barely keep up with his notes. He's going on to equations that can be used to figure out wave celerity (speed), using the language and notation of the sciences to do so. Isn't this just Speed = Distance x Time? These students have done that in high school, he could draw on that information and have them apply it here. Wave celerity seems like something new – but they've done stuff like this before. He tells the students that they'll see why we care about this at the end of class.

I wonder how this topic could be linked to the topics the students are learning about in their majors and other classes; business, anthropology, psychology, education, etc. He wants to focus on the physical science of it all – I feel that that's a stretch for these nonscience majors who are interested often in the social ramifications of the science – is there a way to mesh the two? I know he has a goal of trying to show the students that science is not too hard and that deriving them can make sense based on what we're looking for... he uses reductionist techniques to help students make sense of the phenomena and how scientists quantify it. I agree with his goal, I'm not asking for a watering down of the information – what I'm asking for takes a lot of time though...it demands giving students other ways to observe and understand the questions being asked about the phenomena – how would they determine wave speed if they had to?

Jim goes through slide after slide, the students ask no questions. He lays out a simple and clear explanation of everything and today is not posing many questions to them. He talks, they copy. He's told me he dislikes this mode. He said he will infuse movies and film clips into future lectures – make it more interactive. That's good. It seems to me that a lecture all about moving water should actually show some moving water! How about a basin of water sitting on an overhead projector and the professor makes ripples and waves in it? The students could see that ...

Jim asks the students, "Where does a deep water wave officially become a shallow water wave?" There is no wait time, he explains the answer. There is a sense that it all needs to keep moving in here – not a lot of opportunities for students to reflect at times. And speaking about reflecting, so many students go to the beach over spring break, why not move a lecture like this to right before break and not after? Why not get the students primed and ready to see and think about waves!

Jim tells an interesting anecdote about surfers in New England and how they know the fall is the best time to surf, how they rush to Rhode Island to catch the early waves that have the longest wavelengths. A neat story – very applicable and thought provoking. The students around me comment to each other during that story although I can't hear what they are saying. That is the kind of story that could be used to get the students to think more deeply about the topic. It could serve as a good problem-posing type of question.

The students and I work on an activity from the workbook that uses the wave equation. I don't have a calculator so I have to really work to make sense of my answers, I listen to the other students talking and plugging in the numbers. It's good practice. They rush toward the end though, the last question is the key point and they barely talk about it. Jim begins the lecture again and the students are getting too talkative. He, by using great slides of tsunamis hitting land and people running away (or not!), attempts to get students the message that because they are shallow water waves they are moving fast and the water really piles up as it reaches shore. It is amazing to me that these waves are moving so fast! No wonder they are so dangerous near shore! It makes me wish we had more information, how often do they occur? Is there one happening today? Did one happen yesterday? How does the global detection system work? Let's see one of the floating monitors, etc. I want the relevance of this made more explicitly – it is amazing knowledge... Time is up the students are gone. Some of them got it I'm sure. Will they think about wave speed this summer at Cape Cod – who knows... will they wonder about where in the world a tsunami is happening?

Teacher Thinking

Knowledge and Beliefs

Jim's responsibilities as a faculty member and member of his scientific community are manifestations of his status within his community of practice. The following explanation of responsibilities are evidence of his knowledge and legitimate participation in that community. Jim is currently the undergraduate academic advisor for the Earth systems major. He was recently awarded a large NSF grant to set up a computer laboratory and is overseeing the logistics and implementation of that effort. On average he teaches three courses a year, although the semester I worked with him (Spring, 2002) he was teaching four. He serves on four departmental committees (hiring for hydrogeologist, hiring for geochemist, computer, and space) and a number of national/international committees within his discipline. Outside of his own research and teaching he reviews proposals, works on steering committees, reviews and prepares manuscripts, and presents at conferences. Since being awarded his doctorate in 1996, Jim has ten publications and an article accepted in Nature. Clearly, he is working toward full membership in his community as he strives for tenure. Hard work, an unwillingness to say "no" to new projects, and an enthusiasm for his subject matter are all characteristics that mark Jim's beliefs about the nature of his work.

Data from interviews, conversations, classroom observations, and ratings/comments on a 20 question Nature of Science/Nature of Teaching questionnaire (See Table 8 in Appendix I) lead me to suggest that Jim holds fairly dualistic beliefs (Taylor, Gilmer & Tobin, 2002) about the nature of science. This is evident in the following quote

...there are definitely incremental truths that you are trying to approach. You may actually get to some truth, but as soon as you do there's one more beyond it and I don't see it as really ever ending.

I propose that his objectivist beliefs about the purposes and methods of scientific research prohibit a social constructivist perspective. However, I fear misrepresentation if I solidly drop him into this camp – when pressed, for example, he describes the influence that funding agencies can have on research foci and goals (Phase I interview). As such, if I could/should (for purposes of representation) place him along a social constructivist/objectivist continuum I believe he would sit to the right of center. Though he understands that funding agencies can set the direction of research, "unfortunately there is definitely a political component to all of this…certain research is easier to sell than other research" he believes that scientists' work is creative and motivated by a pursuit of knowledge at a deeper level (faculty questionnaire). He generally disagrees that scientific knowledge is constrained by funding, politics, and researcher interest or that socially constructed ideals of worthiness shape its development (faculty questionnaire). He believes in pure research, unfettered by the constraints of culture and society:

> [Climate research] has a direct impact certainly, on the planet in general. Absolutely. But I wouldn't say… I don't think that that's the main motivation for pure basic scientific research. (Introductory interview)

His ratings from the faculty questionnaire portray his thinking on additional nature of science and teaching issues. For example, he believes that scientists are open-minded and objective in their work and that scientists' work is beneficial to society at large. He generally agrees that science and society influence each other. He doesn't agree that scientific methodologies of today follow an Enlightenment philosophy and is unsure whether non-western scientific practices should be considered valid constructions of science. At the same time he questions whether science is exclusive although he believes it is competitive and Euro-centric and recognizes that most scientists are white males. He agrees that women and minority scientists have made important contributions to science. He is unsure whether scientists are unique and special, commenting that "Everyone is unique and special." Jim also believes that his beliefs about the nature of science influence his teaching.

Teaching & Teachers: summary of survey responses

> Teaching's becoming easier for sure. I've taught a couple of courses a couple of times now and they're starting to just kind of flow and it's taking a lot less prep so if I have another deadline it's easier for me now to not worry about coming in the morning about an hour before I have to teach and get some overheads together and feeling like I'm being effective and still having fun in class… a year or two ago I was still spending a lot of time worrying about individual lectures and having good material. That's all getting a lot easier. (Introductory interview)

After Jim returned the Nature of Science/Nature of Teaching survey he commented that it was a challenging survey. I think that his struggle is evident the most in the oppositional answers he gave on matters related to the nature of teaching and students. I also think that his answers reflect a practitioner who is being asked to reflect on and characterize his teaching beliefs for the first time. As such, his answers reflect incomplete thinking about some of these topics. It was also a challenging survey in that it used the language and notions of science education researchers. For example, asking him to take a stand on statements using constructions such as “teacher as coach”, “sociocultural reasons”, and “socially constructed” required him to find the text intelligible prior to accurately representing his belief. In fact, three-fourths of his “Neutral or Don’t Know” responses were made about nature of teaching-type statements. In addition, this survey reflects his beliefs at the start of the research project and as such may not best represent their evolving nature. The data from this survey is difficult to characterize, however. The professors were only asked, using a Likkert scale from strongly agree to strongly disagree, to choose an answer that best represents their thinking. In some places, they included comments. Our introductory interviews following my review of their answers did not afford the necessary time to investigate much of the meaning behind their responses. Below are summaries of his beliefs and thoughts on teaching, most of which originate from the survey and, where available, are further established with other data sources.

Jim agrees that traditional teaching methods and course structure prohibit students from succeeding equally in science. He is comfortable with the notion of professor as “coach” or guide during class and agrees that he should invite students to participate in the scientific community and work to make learning relevant and meaningful to all students. On the other hand, he generally believes that his role as teacher is to present scientific knowledge during class. He doesn’t believe that stereotypes about who can succeed in science influences his interaction with students and is unsure if he should actively create/promote a learning environment that I supportive of male/female/ethnic/minority students equally. Finally, he is unsure about how great an influence he can have on a student’s decision to pursue a career/interest in science.

Schooling & Learning: summary of survey responses

Jim generally agrees that students who have not excelled in high school science should probably not consider a career in science and he does not attribute fewer females succeeding in science to sociocultural reasons. At the same time, he agrees that (perhaps) females have not been encouraged enough in secondary school to excel in science and that they do not enroll in SMET majors equally with their male counterparts. He is unsure if females (and males) drop SMET majors primarily because of poor teaching. He is unsure if anyone can become a scientist, commenting that "It depends on your definition of scientist" yet disagrees that some students just cannot "do" science. At our first interview, after completing my faculty survey, he expressed keen interest in understanding the experience of females in science and in his courses particularly. He wondered aloud, "What can one do, how can one make a course more interesting to females? How do we get more females in science?" He also commented that some of the survey statements about females in science (SMET drop out and poor teaching), equitable classrooms (actively supporting male/female/ethnic/minority students), and instilling a critical perspective about the purposes of science (who creates the knowledge and who benefits from it) raised issues he either knew nothing about or had never considered before.

Students & Learning

> ...maybe for the freshmen just coming into college, [the class] should give them some confidence later on in their college career so that they can actually look at something abstract as a series of numbers that represent something like temperature or salinity with depth and actually be able to say something about the conditions of the oceans at that location or how the ocean is actually working. And that should make them feel pretty good about themselves.

Students learn in this course by coming to class, taking good notes, reading their text, completing the in-class activities and doing well on exams (classroom observation notes). That is what they "do" to learn, "how" they learn, according to Jim, is harder to decipher. The descriptions he offered about student learning in his upper division courses create a very different image of student activity than what I observed in this course. The fact that he was uncomfortable and frustrated with the teaching of this course speaks to this issue, he values conversation, back and forth, problem posing and solving, and student activity. He believes that students learn through many activities, those listed above and, as importantly, by interacting with him., "[I] spend a lot of time working with students one on one which is great and I love that, it's my favorite of this job just having face time with all these great young people" (Introductory interview). Perhaps that is why he marked unsure on the survey statement, "students learn the content mostly through individual study outside of class". He wanted learning to occur during class, telling students to, "Sit back and follow along because this is all in your book and you don't need to copy it all down" (Classroom observation). It was as if in place of the physical and verbal activity he was able to promote in other courses he tried to create a place for, at least, students' mental activity.

Along with trying to improve students' declarative knowledge about the oceans, Jim was also trying to enhance students' understanding about who does science and how scientific knowledge is produced. He puts it this way,

> At the end of the course I think it would be really great if the students end up knowing some of this stuff about the Earth and the way it works. On the other hand, being a little bit more confident about scientific process that they can actually figure a lot of this stuff out on their own. ...You know environmental issues right now are such a big deal. And I think it will be good that some of these students, this might be the only chance they have to actually learn about how scientists do research, what these ideas about global warming are actually based on, who's actually doing this work. I think if you just read a New York Times, or worse, the Wall Street Journal, you might have a different perspective of where these ideas come from and who's actually coming up with them. And these students will see that a lot of these ideas really make sense on a very basic level. (Introductory interview)

Content Being Taught

Jim believes that the content of Introduction to the Earth's Oceans is intrinsically interesting and important to all students stating, "It's part of their world too. So many of these young people, they go to the Cape in the summer, they're at the coast, they go into the fish store, I mean it definitely directly affects them" (Introductory interview). He views the course as a simpler version of an upper level physical oceanography course that he teaches through which students learn important topics and realize the value and usefulness of their learning in their everyday life. His goal is to "distill" (his word) the content down for these students and he disagrees that they are more interested in passing his course than learning material, believing instead that

> there is some component brought to the course that makes the student thinks that this does indeed affect them in their daily lives, whether it's the price of fish in the fish store, whether or not we're going to have a huge tax on gasoline in the next few years, whether or not the US should or should not be involved with Kyoto. (Introductory interview)

Section 2: Dr. Mary Gibson: Context

Personal Context

I first met Dr. Mary Gibson and the Introductory Genetics team at a planning meeting in the fall of 2001. Dr. Gibson sat amidst 3 graduate students and her colleague, Dr. Liza Richards, surrounded by laptops and piles of paper, trying to get her computer to do her bidding. "Oh! I'll get this yet!" she announced smiling. It was at that very first meeting I believe I got to know something important about Dr. Gibson.

Dr. Gibson did not match up to my preconceived notions of a biochemist and full professor at a major research university. I had never met a biochemist before, I wasn't even entirely sure what a biochemist did. I had expected a very serious woman who, in the manner of some, subtly let others know their power or social status. I guess I expected that a full professor of biochemistry would put on some "airs" (Mary would joke about that even now, "Oh, I've got "airs" alright!" she would say). I had also wondered if she would feel as if she was doing me a big favor by agreeing to be part of my research. However, my stereotypes and preconceived notions were far from reality. To me, Mary appeared unpretentious, candid, interested, and affable. From the start, she was overtly welcoming and appreciative of my participation and interest in her new course. At this very first meeting she sought out my thoughts and ideas about her course. I was taken back by this – I also felt very lucky. Over time I came to realize that she is a typical person, dealing with the mundane issues of life, family, and career that we all struggle with – she, however, has a keen mind for biochemistry, a professional ability to manage people, and good mix of effective study habits and history that has gotten her where she is today (notes, 11/01).

Another component of Mary's unpretentiousness that enabled me to get to know her was her "look" (which I later realized was her "uniform" as she jokingly confessed that she didn't think she could work in industry as they might expect her to dress up for work). On an almost daily basis Mary is dressed in a comfortable T-shirt, loose slacks, sneakers and a black suspenders-type back brace. Her waist length brown hair is tied loosely in a ponytail. Her look reminded me of the first time I met respected science education researcher, Angela Calabrese-Barton at a national conference. She got up to speak in jeans and a T-shirt while many of us attendees sat smoothing skirts and adjusting ties. I always remember that about her when I read her work – I always appreciate that appearance and the simple message it consciously or unconsciously sent. With respect to Mary (though I may be overemphasizing the issue), I believe this characteristic when described alongside the context explored below is integral to understanding her way of being as a teacher and person in the world. It also illustrates the insidious nature of the societal beliefs many of us hold about science, scientists, power, status and how women should look. One might have hoped that in this situation, with my knowledge of social justice, the nature of science, and feminism, I wouldn't even have found this an issue worthy of surprise let alone text.

Demographics

Mary was raised not far from the university in small town where both parents were science faculty at a small prestigious women's college. She is the oldest of three daughters. The next eldest is a science teacher and the youngest a lawyer. In our discussions, she described how scientific thinking, concepts, facts, and issues were woven deeply into the fabric of her childhood. "I'm different, I was born into a family where science was something we talked about all the time, we talked about what was in Scientific American at the dinner table - I thought everybody did – I had no clue that's not how normal people live"(Phase I interview, 2/02). Her mother was an exceptional science illustrator and early in her high school years Mary's focus was more artsy than scientific. However, a unique turn of events caused a change in her personal interest in science during her sophomore year of college.

> My crazy father took us all out of school one fall to drive across the country to California. When we got back the year was almost half over and they wouldn't let me start my junior year – I had to redo a half-year of tenth grade coursework. One of the courses I had to take again was Chemistry. Now, the year before I wasn't interested in Chemistry – I didn't even do very well. But the second time through, I don't know, it was like a light went on and it made sense and I loved it. That was a big change for me." (Ph II, conversation, notes, 5/02)

Following high school, Mary became an undergraduate at a nearby city university, double majoring in biology and chemistry in hopes of becoming a doctor. That interest changed over time however and she pursued a doctorate in molecular biology at a neighboring state university.

After completing 2 years of postdoctoral research at a California State university she came east and accepted a faculty position at her current university. Twelve years later she was promoted to full professor.

Dr. Mary Gibson has worked as a biochemistry professor at the university for twenty years. In that time she and her husband (a computer engineer) built a home near her parents and are raising their 11-year-old son Christopher. Her father passed away some years ago and she and a sister share the care for her mother. When I first spoke to Mary, I inquired about her life away from the university. She explained how, at that time, a huge chunk of energy was being devoted to finding a new live-in caretaker for her mother. "It's a constant issue and a worry, getting good care, knowing she's alright" (Phase I, conversation, notes, 11/02). Her son Christopher also consumes much of her "non-university" time. She speaks frankly of his impact on her life and how parenthood changed the nature of her life as a scientist/professor. So too did a back injury requiring surgery a decade ago.

Her time at the university has always been a whirlwind of research, teaching, meetings, managing students, writing, and planning. Now, as a parent and person with back problems, Mary describes a constrained sense of time and productiveness. To compensate, she has built up her support structures and made clear her abilities and boundaries. No more can she spend all night in the lab or at the computer writing proposals. Meetings now take place in the morning and graduate students are free to call her in the middle of the night if they need assistance. In the following narrative, I attempt to bring together the valued and engrossing components of Mary's life to illustrate my understanding of her life and work.

The narrative, A Day in the Life of Mary Gibson, is intended to represent the day-to-day responsibilities and commitments that support and constrain Mary's efforts to be an effective scientist and teacher. The source for this story is the combination effect of my interactions with her and Liza during the year we worked together. During that year, we talked about life at home, the workday, hopes, expectations, and frustrations that move her ahead or hold her back. I met Mary's son, her mother, her sister, I visited her home, I listened to her and her sister discuss family issues and past history. At times our conversations became very personal. The source for this narrative is also derived from my life as an educator, wife, and mother as I draw on my own experiences to tell her story. Italicized quotes by Mary are woven into the account to further enhance its effect. The people mentioned in the account are real though their names have been changed.

A Day in the life of Mary Gibson: a narrative account

You want to start on that do you? Well, life goes in stages. When I first came to the university and I was hot to get tenure and I had to get the lab running and operating and I had to get the grant money in and I didn't have a child. I was here all day, everyday - the weekends - all the time. So there was sort of that period of time. Then, my life changed in a big way when we adopted Christopher in 1990, so that was big change in my life because I had never had an infant before – that was something else again. Then, in 1994, I had back surgery. So, those are two things that changed not only what I am able to do physically… and what I want to do mentally changes in a way when you have a child. You really have to worry about those kinds of issues. So I try to stay flexible and when women ask me what's the most important thing about your career the keyword for me is flexibility because if I had to be there from this time everyday to this time that would be extremely hard for me. Not only because by this afternoon I have to lie down before I go to a meeting tonight, it's not like I have a choice – so in the olden days before my back I would not have – I would be there all day long and be there all night and that's just the way it is, but I can't do that anymore. I really had to readjust my own mental way of thinking about things to do that. When the surgeon said to me, "You need to change this…" – I said to him, Yes yes I know." But it's like when people say to you, "A baby comes into your life and changes your life!" and you say, "Yes, yes, yes" and you don't really have a clue and you are 4 months into it and you have no idea what your name is and then you realize, "Oh, this is what they meant that you'll get no sleep the rest of your life." So I really have readjusted my priorities and what that means is that, some things get less attention or have attention at different times then they used to… (2/02, interview)

Morning

Talking. News. Noise. What?!? I slap the alarm to turn it off. 6:30 am. John is already up. Tough night. Was I really emailing Liza about the course at 1 am? I sure hope my grad student figured out that problem. Eric will have to deal with her today – I have too many meetings. I rise slowly as I have all these years since my back surgery. It feels pretty good now, it's morning though - that can change on a dime.

Let Christopher sleep another half-hour – he'll make the bus. He has a social studies speech today – the sleep will do him good. I flip on the computer. I wonder how mom is… I hope the new babysitter is all set up for her – I hope this one works out and we don't have to start that process again.

My email is still bursting – can't these messages just go away at night and we start each day with a blank slate? I could keep up then! I peruse the names, making sure I've answered the urgent pleas for help or thanked those who've answered mine. Oh great, today's hiring meeting will run overtime, into the next one now, there goes lunch. I can't stay past 2 – they know that.

"Christopher! Time to wake up!"

John is off to work after a quick breakfast. I remind him as he leaves, "See you for dinner and then I have a meeting till 9."

The morning has taken off.

I help Christopher get ready for his day. Try not to rush through breakfast, talk about his speech, about this afternoon, about this evening. Has he got all his stuff? Homework? Lunch money? "No, today is not a good day to have David over – tomorrow is better – well, I think it is, let's talk later about it okay? His party is tomorrow? Right. Yes, we have a present. Here's the bus. Good luck today! Bye!"

I stand in the quiet for a moment – it's a beautiful spring morning.

The Work Day

Now I always tell anybody who enters my lab, my situation is one where it's absolutely up to them, if there's something going on they want to talk to me about, they need to call me at home, email me, send me a note in the mail, whatever, get in touch me with, because that's the only way I can know what's going on in a day to day situation. And if they are having a problem and I don't know about it how the heck can I help them out? (2/02, interview)

On a day to day basis I really have to assess what the top priorities are of the day. I have to be really careful not to get sidetracked about things which will leave me off somewhere in some minutia that really isn't as important and try to stay on track and stay focused on what needs to be done for that particular day. And this is what is it, that things are being done deadline by deadline – so I don't have too much leeway before the next deadline – and so I need to keep things moving along. (2/02, interview)

8:15 am. My office is an organized mess of "to do's" piled high on every available planar space. I've got 45 minutes till class – enough time to complete the final slides of my genetics lecture and consider where we might be on Thursday. Keeping up with a brand new course, and one for non-majors to boot, is taking up way too much time. I should check with Eric on how Amy's work went last night after her distressed call. God I hope he never finishes that post doc – the lab won't be the same without him.

"Mary, hi! The students have an OWL homework assignment do this week, I want to go over the topics I'm questioning them on," announces Liza as she enters. So much for Amy's issues, class time is approaching. Liza continues, "We need to coordinate this. I'll plan ahead tonight and get back to you, maybe it will make the lecture planning go smoother. I think we should include the NOVA discussions about cloning in the lecture next week too. We want them to talk, we want their ideas. Oh, and any word on the teaching grant? There is still so much to do!"

Before Liza and I leave for class I check email and voice mail, 10 new emails and 5 voice mails. Pam is reminding me about the dates of the fall conference, I need to get back to her. Lila wants to talk about the faculty positions before the next interview at 11:15, and Mike wants to meet to discuss the grant proposal for the new equipment. Right. And the meeting scheduled for 1:00 is now at 12:30.

The day begins. As long as I'm home by 3:00.

After School

Even if I didn't have this problem with surgery on my back and all, I would make every effort I possibly could to be home with my son in the afternoon because for me personally I've found that there is very little time to spend with your child if you get home at 6:00 in the evening then you feed the kid and he's in bed. And in the morning the bus comes. It comes practically before the sun gets up these days and so there's very little time… I need to be there with him, I want to be there not only to interact with him but find out what went on and see how the homework is going…(2/02, interview)

Christopher arrives home tired but content. His speech went well! The teacher told him to change a few things on the written work but everything else was fine. We celebrate with a special snack and chat about the day. We agree he can read for 45 minutes and then we'll start homework.

"Let's go visit Gran first though, we'll finish our snack with her and then come home. Let's see how her day was." We walk down the hill to mom's.

Back at home. Christopher begins math homework I head to the computer. If he can work alone for an hour I can respond to some emails and finish my notes on our equipment needs for the grant proposal with Mike. A new email, one of our papers was accepted, needs revision though. I'll forward this to Eric for starters. Good news.

After 45 minutes Christopher is running out of steam. I let him work on his English story at the computer while I lay down. I couldn't make my meeting tonight without giving my back a rest.

John comes home. Dinner. I'm off to another meeting.

Evening

I found the balance of it to be difficult and that's why the flexibility of it is so important because I can say, if I need to spend a couple of hours with Christopher in the afternoon that work is not going to not get done it's just going to get shifted to some other time so it gets shifted to night. So after he goes to bed I always work a couple hours. Now last night it was longer…(2/02, interview)

8:30 pm. The house is quiet. I need to be in bed by 11:00 tonight. Talk to John. Review an article. Respond to emails. Organize notes from interviews. And when am I going to that conference in Chicago? It's 11:15 now, I'll figure that one out tomorrow.

…and this is how I operate so – in my opinion this business about juggling homelife and worklife is one of the most difficult things to do - and in my life, the way I juggle has depended upon what phase of my life I'm in. (2/02, interview)

Types & Years of Teaching Experiences, Preparation to Teach, Continued Learning Efforts

Mary has taught classes for undergraduate and graduate biochemistry majors since she began at the university 20 years ago. For most of her career she has had no "formal" training in teaching, "I don't know about the rest of them, but in science, most of us are not ever taught to teach, we just teach. The first time I ever taught was here, in 1982" (6/02, interview, 705). Mary enjoys teaching though states that early on in her career conducting research and getting published were paramount. She has since tried to find the balance between her teaching, research, and service responsibilities. Within the last 9 years, Mary has joined professional development-type projects and programs to enhance her teaching. She received a Biochemistry teaching award in 2002, the Center for Teaching and TEACHnology awards in 2001, was nominated for the University Distinguished Teaching Award in 1998, and was a mentor for the Lilly Teaching Fellows Program in 1993-1994. The TEACHnology project was integral in that it fostered the integration of computer technology into her courses, and was a precursor to her receiving money from a Dreyfuss Foundation grant for course improvement.

During this time Mary, Dr. Liza Richards, and others were developing ideas for the Introductory Genetics course and in 2001, when the Collaborative introduced its Fellows program focusing on pedagogical change, she applied. These projects have not only appealed to her motivation to improve teaching but have tangible benefits. Through TEACHnology she received a lap-top computer. The Dreyfuss Foundation grant and Collaborative have provided her with money to support Dr. Richards.

Computers and money are integral components to the success of the Introductory Genetics course and thus Dr. Richards's participation cannot be over-emphasized. Mary has stated repeatedly, "None of this could have happened this way without her!" Liza Richards, a Ph.D. in biochemistry and computer consultant/web designer, has been in the employ of other science professors at the university as well as text book companies to infuse web technology into science education. As a co-developer of the Introductory Genetics course her primary responsibilities were to design and make usable web-based tutorials for the students on-line homework assignments.

Mary met Liza years ago following Liza's career change from a physical education teacher to a biochemist completing her doctorate and post-doc in the biochemistry department. Liza's interest in teaching, fascination with the computer, and love of biochemistry lead her investigate ways to combine her interests. She began learning about the design of tutorials for biochemistry courses and, instead of seeking a faculty position, has chosen to focus on this aspect of the science. The years she spent teaching physical education at an alternative high school have confirmed her inclination toward innovative and non-traditional teaching styles that engage students in active learning scenarios. She constantly seeks out new ideas about teaching, learning, and assessment and Mary counts on her to continue to challenge and reshape more traditional teaching genres. It is because of Liza's attendance at a workshop I co-presented on gender issues and science that I was invited to research the Introductory Genetics course and Mary's teaching in the first place. Always searching for a critical perspective, both Liza and Mary agreed that another set of eyes might assist them in the development of an effective course.

Academic Context

Because so much of this paper focuses on Mary's actions as a teacher, the following narrative account of one of her classes is presented below. Through this writing, I hope to represent an image of the course that is useful to the reader as I draw on Mary's actions in later sections.

A Day in the Introductory Genetics classroom: a narrative account

> Class meets on the 10th floor of a large science building on campus. A group of students and myself ride up in the elevator together. It is over a third of the way through the Introductory Genetics course. Discussion in the elevator is muted. I know one student by name because I have interviewed her – the rest say hello with their eyes or not at all. It's early though for students – 9:23 in the morning and it's cold.
>
> The class convenes in a small library type meeting room with just enough tightly packed desks to accommodate the 20 students who come to class. Enrollment is at 22, the average that shows up is about 17. Today most of the desks are filled. I help move some seats around to organize things. The instructors, Mary and Liza, and a teaching assistant are plugging in laptops, moving tables, and talking amiably. Large windows open to the sweep of the valley north of us, we are so high, it is an amazing view. The

students wait silently, sipping coffee, gazing out the window, whispering to each other. A student approaches Mary, one of the upperclassmen, to tell her about a great show he saw on the Discovery Channel last night. She stops and listens to his descriptions, "Yea, I heard they were looking into that. I wonder where it's all at now?"

Mary glances at the time, 9:30. "Okay okay, let's get started." I wanted to first have you look at these articles that Jeff is passing out. There are three of them, from WIRED News. One is about the UK approving human cloning, the other about the creation of a protein atlas, and the last about designer babies. I met the author once, Kristen, very interesting. She isn't a scientist but majored in writing and now just knows a lot about all of this because she loves it. You never know what you'll be doing in the future! Let's talk for a minute about the protein atlas." Mary reviews the article for the students, reminds them to read these for themselves and ask any questions in the next class. I find myself reading the article about designer babies, it's fascinating! I constantly struggle to remain an observer in this class and not get too intrigued by the science but it's difficult.

A student arrives a few minutes late, "We'll get you alarm clock and next time won't let you in!" she tells him half-jokingly. At 9:43 am Mary begins the Powerpoint lecture presentation– the first slide reads, What is a Gene? She starts by telling the story of the human genome project, explaining who got it going, where the money came from, and where it is now. "We will go into this more deeply in another lecture." I wonder about these male scientists and why there are no females or people of color highlighted in this work, I believe that this is important for students to consider.

Mary shows a slide of sex chromosomes. "The nice big one here is the X, the little, uh, one here is... the Y, the male" (students laugh) – "I'm sorry Liza, I just had to say something!" Mary continues discussion of the sex chromosomes. Mary likes to joke a lot, to get students involved through humor. When they get the humor the students tell me they like it and like her. "She tries to make it interesting" commented a freshman female.

By 9:50 am she is on to a slide with a diagram of DNA showing the structure of the cell and then in closer images where the DNA sequence fits in. A good visual for me. I can see how DNA is wrapped up to form proteins. She mentions the term *highly conserved* proteins and asks students what that means. She quickly begins answering her own question when Ian, a graduate student in biochemistry raises his hand, "it means they won't change their structure." Mary responds, "Right, it's amino acids..." Ian answers a lot of questions in class.

The next slides are on DNA sequencing. She explains how it's done today and how differently it was done when she was a grad student. She laughs, "Now, it's all done by computer, if you want me to tell you a funny story some time I'll tell you how I blew up gels at 3 am one night...!" This is not the first time she alludes back to how the science and technology have changed dramatically in 20 years – she is very keen for students to understand the changing and quickly evolving nature of this discipline. She continues describing how with computers each letter of the DNA sequence is made to glow and the machine reads the sequence. A female, senior in history, from the front row asks, "If a gene is wrong – is there a way to know what the right way should be?" I didn't understand the gist of this question but Mary did. "Yes," she answers and goes on to explain. The same student asks, "So, if it copies the gene wrong – can it ever just occur, get something wrong?" Mary explains, "Now we know there are a lot of ways to mess up the DNA, like by the sun (she explains about mutation and too much lying out in her youth) but your body has proteins that go around and repair DNA." She continues with an explanation of how cancer represents a system that is not working to repair mess-ups then she reminds the whole class, "Please! If there are questions holler otherwise I won't know...!"

10:01 Mary begins showing slides about gene sequences and tells the students, "We'll do some things to figure out how you find a gene in the sequence." She goes on to explain how genes can be on in one cell and off in another and exactly what a gene is made of. "What I want you to know today is what a gene is, its basic structure, and that you have a place where control takes place." There seems to be a lot of information coming at us and that this statement would've been useful at the start of class. At the end I should be asked to self-assess, "Do I know what gene is? Do I understand its basic structure? Do I know where the control takes place?" Perhaps an activity like that would get more students talking and participating in class, it is common for a few to ask all the questions.

A female, senior science major asks, "So the promoter regions is noncoding?" "Right," Mary answers and explains further. "Now," says Mary. "Look at this sperm chromosome map. Will this sperm make a male or female?" A majority of students murmur. "Male." She continues by talking about traits being characteristic of the mix between 2 genes.

By 10:20 the slide presentation focuses on showing how different organisms have different numbers of chromosomes and there seems to be no rhyme or reason to this as far as scientists can tell. Some higher order species have more genes or fewer genes... I find this fascinating!! I have about 3 questions I'd like to ask about this – but the students have none, why is that??

This leads to a slide set of 8 funny political cartoons about DNA and the number of genes we have versus other species, etc. Students laugh. Slides of scientists working on the project are always white males; "There are no women in this field!" jokes Mary. She reminds students, "You have to know enough about this to make decisions. The system is set up to use the information in any way they can, it can work for you and against you – you need to know." This is a common sentiment, she knows how our genes are being researched and used and the potential fall-out with health insurance or determining our future health and wants the students to get it. Do they? I'm sold.

At 10:35, she links up to the NOVA website where the first slide shows a female technician working on a sequencing computer. Is this where the women are? I don't believe so but it's what's shown! The site has questions about DNA for the general public to answer. Mary had stated in an earlier meeting that she liked these questions and hoped it would generate good discussion. The first question is if you would want to be tested for a genetic disease that has no cure. Four hands go up immediately, a few from students who rarely if ever talk in class.

A female student from the back responds, " In case of adoption, my dad is adopted, I'd like to know if there is something about heart disease..."A male student from the center comments, "Alzheimer's is on both sides of my family – should I know about it? Do I have to tell insurance companies if I know about it?" Another female adds, "I would not want to know, I'd be so paranoid. The information would be more than I'd want to know, I wouldn't be able to live my life normally." A male psychology senior remarks to her, "but then you wouldn't be able to take proactive stance, you might want to live life as if it's your last day..." The female senior majoring in history announces, "This is completely subjective, no one could say that yes or no is the right answer."

A few other students have their hands up. Mary says, "This is on the NOVA website, we'll pick up here Tuesday. Reading assignments will be up tomorrow on the website, get here on time!" Unfortunately, there never was time to get back to these questions in the next class.

Class breaks up quickly. Two students approach Mary to ask her additional questions about finding out about genetic diseases. One student inquires about a missed quiz. Mary leaves the room at 10:50 am after talking to students, Liza, her teaching assistants, and gathering up her laptop. She smiles and explains to me that she's off to figure out next Tuesday's class notes.

I leave class feeling slightly dizzy, there is so much going on in this class. I'll meet with Mary next week to share my thoughts.

Cultural Context/Department Context

My department is relatively small – there are I think 13 or 14 faculty members on the list, though not all of them are teaching faculty so there are different levels – and we're not a very large department so compared to biology we're only, let's see, we have 170 majors, so it's small, and we teach a small number of classes in comparison. But our focus is to teach students who go on into professional science – they go to medical school, they go to medical school, they go to graduate school, they go into the biotechnology industry at the level of scientists and not in a more general category. These people have a very strong science and math background. So, as a result, our majors, they go and do great things. And ... we, of course, get ragged on because we don't have a large undergraduate population. Well, we could certainly increase our number of majors, but our argument again is that we're going to require them to take hard courses and there have to be standards – and if you flunk all these courses you can't be in this major. And that's what we come back to... (2/02, Mary, Phase I interview)

The above quote illustrates much about the culture of the biochemstry department. According to Mary it is a place where students, if they have what it takes to get into the major and learn what they need to before leaving, get deeply enculturated and prepared for the community of science professionals. It is a place where novices interact with experts to move deeper into a community of practice (Wenger, 1998). Its' graduates are successful. It is not, or at least up until the development of the Introductory Genetics course has not been, a department where undergraduate nonmajors are often included in the goings on. Students must be successful in prerequisites to get into the major and then be prepared to focus and succeed in rigorous courses in order to remain. There are standards. From the outside looking in it appears to be a high stakes place appropriate for a small percentage of students.

Based on data from the university's Center for Institutional Research (See Table 9 in Appendix I), there are one-hundred and sixty-eight undergraduates majors in biochemistry and molecular biology. Almost 2/3 of those students are male and whites comprise the majority. However, the lack of a gender gap in biology is becoming evident in the department's faculty. Mary states that almost half of her colleagues are women including her department chair,

> ...these are all strong women, these are not women who are easily pushed around by the system or by anybody. And it works well for us – and that's one of the reasons I like to be here because when I've been on one of these search committees and people are talking about what do we want? They're always talking about we want somebody who's good at research and we want someone who's good at teaching, and they care about all that! Never have I heard anything mixed in that's denigrating toward women or negative in any way like that. The flip side of it is that nobody sits there and says, well, Mary has other things to worry about so we should give her a break'"(2/02, Mary, Phase I interview).

In this quote the discourse of gender neutrality (Eisenhart et al., 1998) is apparent in departmental culture. It is "fair" place; robust and professional. It does not make departmentally sanctioned allowances for differential treatment of faculty based on a individual's personal situation. Again, there are standards. However, it is also flexible and supportive of its members in important ways, "the flexibility is really the culture of the department as much as anything" explained Mary. For example, the faculty, at times, cover for the support staff so that they can go to lunch all together and not have to leave anyone behind in order to follow the university rule that all offices must remain open. In Mary's case, this flexibility allows her to set times for classes and meetings based on her physical needs and she is not questioned. She meets the standards.

> The flexibility comes from having had the education. I have Ph.D., I'm in a position of having tenure at a university, and that's really what carries. If I went into a position where I was in a biotechnology firm or something like that, then I would have a different set of requirements ... I would first of all have to dress differently, I mean that's an aspect of it, but also, I'd have to play a particular kind of game. You need to be in there at a particular time and stay for a particular length of time and that's part of what counts – I mean, the kind of science we do, that's not what counts. What counts is how productive you are – how good you are at your job – not whether or not you're in at a particular job. (Mary, Phase I interview)

Classroom Context

Mary states many reasons for developing and teaching the Introductory Genetics course, primarily it is, "Not to make students into scientists, but to have them make connections with things they hear or know...to help them not be afraid of science, to... look toward careers or interests in an area that they have not thought of before" (12/18 notes). She hoped to offer students a hands-on relationship with what's going through a lab exercise, offer them real images of what DNA looks like through Powerpoint images, and make a bridge to reality and help them figure out logical ways to approach things using computerized tutorials and individual projects (meeting notes, 11/29). A few of the major issues facing Mary and Liza as they designed the course was to question how to change or ease departmental standards for the non-majors, how to interest and motivate students, and how to present the topics in an accessible way (notes, 11/01). To learn about and deal with these issues, they created a course structure and classroom culture that attempted to take into account nonmajors' physical, mental, and emotional needs.

To that end, Mary tried to create an atmosphere of familiarity in the classroom by the language used to convey information. She explicitly explained to students that she wanted to demystify the language of DNA and how it could appear at times "scary". She constantly implored them to stop her with questions or comments about the topics. She sought their laughter and comfort by adding many humorous moving animal images and related political cartoons within the Powerpoint presentations. Mary greeted students when they entered her classroom, paused at the beginning of lecture to assist students and teaching assistants with paperwork and spoke to them in an informal way as she and her team worked out the technical bugs that plagued them early on with the use of Powerpoint and web-based presentations.

The standards of the biochemistry department were not abandoned however. She was noticeably frustrated with frequently absent and tardy students. She was bothered by students' classroom ambivalence, unwillingness to complete homework, and lack of motivation to meet with her outside of class for extra help. Because she so highly holds students responsible for their own learning (discussed further below) she did not bring these up to the class as issues as that was not the best use of class time and the students should "know better".

Teacher Thinking

Knowledge & Beliefs

Since her postdoctoral work in 1980, Mary has been supported by almost three million dollars in research funds from NSF, the NIH (National Institute of Health), and smaller grant funding organizations. She has received 22 honors and awards that have further supported her research and teaching. She has attended 15 national meetings as an invited speaker and has authored 30 publications in biochemistry journals. Clearly, Mary is a legitimate, full participatory member in her scientific community of practice. She draws on her content knowledge (Shulman, 1986) as she reasons about what and how to "distill" (Mary's word) her scientific knowledge and make it accessible to students.

During Phase I of the study I sought to understand and converse with Mary about her beliefs about teaching and teachers. Our initial interviews and her responses to my Nature of Science/Nature of Teaching questionnaire (See Table 10 in Appendix I) assisted in my efforts to clarify her ideas. Below is a summary of her beliefs about teaching and learning in the context of this setting.

Teaching & Teachers

> I think the important thing to making something scary seem not so scary is to make it relevant...relevant and at a level that is comprehensible to them. So in my mind, DNA is relevant but it's even more relevant if you can point out to someone the point where it's made a difference in somebody's life or the ways that it might encroach on their own life or the way that it might help you in the long run. And so those kinds of connections, I think if it makes it important as a topic to somebody then it's not something they are not necessarily going to do in their job the rest of their life but they do feel a connection to it and then I feel like it's easier for them to, instead of running away from science, say, "Okay, maybe I can understand this..." Mary, Phase I interview

Mary believes that her major role as a teacher is to present scientific understandings to her students. As the expert, she is highly responsible to choose the important topics to be learned and teach them in a way that makes the knowledge easily accessible, interesting, and relevant. She sees good teaching as connecting to students' thinking and opening and expanding minds. A major component of this belief is the awareness that teachers must have regarding the language of science. She talks of science as being a different language and how students need to understand how to make sense of the language. In her words, "I think one of problems that we have in science is that we talk a different language and to a lot of people the science of it seems to be scary." In regards to her course, she wants students to understand the language of DNA and its social issues so that they can use it and find its meaning in their lives.

Mary embraces teaching as telling and is comfortable with the metaphor of professor/teacher acting as "coach" or "guide" during class "part of the time". With respect to the former she vigorously points out that in order for teaching to be effective teachers need to tell students things that they are interested in and can connect to. This can be accomplished by facilitating questions and guiding the understanding of information. Such strategies allow her to realize her students' level of understanding and subsequently monitor and adjust her teaching. Such adjustment is mostly related to improving students' conceptual knowledge and increasing their interest in the subject. She believes that although teachers are a major influence on a student's decision concerning possible science careers she does not feel they are the greatest influence nor should they be. Instead, a student's ability to be responsible for her own learning holds more sway in that regard regardless of the teacher's hopes and strategies. However, she agrees that females have not been encouraged enough in middle/high school to excel in the sciences.

Students & Learning

For Mary, learning is a rigorous systematic process of engagement with course material and issues through reflection, self-interrogation and action that inquires further about the new information and/or makes us of it in relevant ways. It is guided by an obvious expectation of hard work and attention to the required tasks set out by the instructor as she guides student understanding. Mary offers a glimpse into her own process of learning as she describes the preparation of her Powerpoint presentations:

> I think that most people don't pick up things from reading. Reading and learning are not necessarily the same thing and one of the reasons that I prepare lectures the way that I do is because that that's how I learn. I take the material, I figure out what the important points are and what things
>
> connect to that that I have to know and my way of learning about it is to process it into something that's written down... here's the thing that I think is important and here's the thing that's connected to that that is important.

Her hope is that students could and would deeply reflect on the information presented to them. However, she realizes that there are serious constraints to students' ability to learn. One is students' interest in the subject and the other being their study skills (which are linked to and affected by student interest). In regards to the Introductory Genetics course, she comments that

> I think what we're trying to do is a difficult thing – we're trying to take people who have lots of different backgrounds and trying to teach them something they are not so sure

> they want to learn – and I think that it's just going to take some effort on our part. (Mary, Phase I interview

Though interesting students and keeping them motivated are necessary parts of good teaching, they are not enough to insure every students' success - "and despite what my department head says, my overwhelming enthusiasm is not going to carry the whole thing." Student commitment to learn and expertise in how to study material play a major role in student learning. Mary speaks often and vehemently on this issue:

> I think you can only write things down so many different ways and tell them so many different ways; if you don't read the instructions and you don't do what you supposed to do [then] the grade suffers whether or not you've actually learned it.
>
> So all I'm saying is that I think that every single student has a responsibility in a class and if they are not, by the time they've gone through the first third of the class, getting it because their exam grades are not good or because they have whatever red flags there are that are telling them there's a problem – who's responsibility is it to figure out what to do about it? Now, as a professor I think it's important that I know where the students are, but there is no possible way to know everything about all of them. I think it's incumbent upon the student to take responsibility and to take action because it's not like there aren't resources there – not only are there us but there are the TAs – there's other ways to get assistance. We made ourselves extremely available.
>
> And I think it's important for us to figure out these ways to get those kinds of things across to the students but the onus is on the students, or the university, to figure out the best way to learn the material. Because all we can do is offer them options.

What are the options Mary is speaking about? To her, the way she organizes the curriculum and is accessible to students offer students many options to learn. Her curriculum uses straightforward presentations that make constant pleas for student questions and comments, reading assignments that highlight concepts and offer real world relevance, a hands on laboratory exercise, online tutorials for active learning, a student chosen project, and quizzes and exams to further gauge understanding. She is also readily available to meet with students outside of class for extra help, to discuss relevant topical issues, and to inform her of personal issues affecting their learning and performance. Mary strongly believes that these options, coupled with a responsible student attitude, can lead to a high level of learning for any student. However, I don't want to characterize Mary's curriculum as static, on the contrary, especially because it is a new course, she attempts to gain understanding of student learning and adjust her teaching/curriculum accordingly based on traditional summative and weakly formative assessment techniques.

Mary believes that student learning is slow at the beginning of a semester as students become comfortable with how things are run in the course and get a feel for the level of understanding expected of them with regards to content. She explains how, in a few short weeks, students begin to "get it" and how she gauges their understanding. "Even just in sort of getting a feel for when to ask a question [I look to see] that they are using the words in the right way, that they are able to incorporate the knowledge in the ways that they ask the question." Over time, students catch on and are able, using the options presented in her curriculum to make relevant links and increase their interest. She describes this further in the next quote:

> So… part of it is hard because in the beginning they have to get the beginning pieces of information and start to fit the puzzle together. And I think that was true for the LIR [learning in retirement] people - in the beginning they weren't sure how all this was going to go – and then I think with time as they got a little bit more information and they saw how things actually work in the cell, that it's not random, that there's actually a plan there, then it's clearer to them and they can start to be able to understand more about certain kinds of things in general. That's part of the reason for feeding them information from the popular press to try to keep them realizing how relevant all this is to what they are supposed to be learning, to what they want to do in the end, and to make a kind of connection. I think the things you learn the best are the things you connect to and the things that you use.

Mary believes that almost anyone can understand science if he/she studies enough. She does not believe that some students cannot do science but that "some students don't want to learn science." In her experience too many students have "poor learning and study habits…[and] the expectation that learning 'should be' easy when it is actually hard work".

The "hard work" of learning means that students follow certain spoken and unspoken expectations of a course and take responsibility for their learning. In her view, students learn by coming to class regularly, actively listening to lecture and participating in activities, considering/asking/answering questions during class, completing assigned homework assignments, studying for quizzes and exams, and asking for help outside of class as needed. Students also learn by seeking connections between scientific knowledge and practical life applications and engaging in self-teaching (by completing projects). She gauges learning by the questions students ask over the semester and their grades on homework, quizzes, and exams.

And so what I'm saying is that if you give them all the rubrics in the world to tell them what they have to do to be a good job – I would say that, for example the project we did, that the people who did a good job would've done a good job whether they had a rubric or not. And the ones that didn't, or the ones that really needed help, I feel like we did everything we could within the realm of the back and forth and the time frame to help them but they have to take a certain level of responsibility themselves and I think that's true in life and it's certainly true in college.

Schooling & Learning

They had a poll, I don't remember when it was, but we brought it up with the faculty, because the university did something about how many hours students study and it was something like - it was miniscule! They spend less time studying than they do peeing, I mean really! It's a matter again about what your priorities are - there's money, it's all a matter of how it gets spent. There's not enough time? That's true, but it's finite no matter what so you have to find out how your are going to spend it – what your priorities are. You can't just reread something and consider it learned. Whether it's poetry or whatever it is.

Because Mary places such an emphasis on student responsibility and ability to learn and study, it is useful to disclose some of her thoughts about how one learns to learn. That this section is brief again underscores that though Mary believes that this is a huge issue affecting student learning in her class, it is not fully within her realm of responsibility or ability to fix or change. Nor is it an issue that impacts much curriculum planning. For example, she states, "Yes, there's no question, that somewhere along the educational system kids get turned off to science and I don't really know how to fix that." She does, however, question public schooling's effectiveness in developing good study habits and inquiring minds in students.

...I think learning different tasks requires different kinds of tools and my experience has been that those kinds of tools are not easily learned by people who are taught in the public school system. So you get a lot of kids who come to school who have no clue how to study. How to use their time, how to organize their activities... and it's not an easy thing to do. I think it's a learned behavior – how to organize things so you can get through all the information because the world is full of all this stuff and you have to sort out what is really important and that's the take home message. In some ways it's learning in sound bites ... the take home messages are the important things and what's behind that. I think that part of the problem for the students who are not good studiers is that they have to learn how to do that. We help them the best we can but I don't think it's easy to know who's having problems because their studying is not what it should be.

On the other hand, Mary views a student's ability to study well as an evolution that naturally occurs over their college experience. Over time, she believes students come to understand their own ability to learn and gain a personal sense of what is an acceptable grade for themselves.

> And there is certainly, I think by the time you get to be an upperclassmen you've got more of a handle on what is more acceptable or not in terms of the levels of performance.
> I: And I think you better understand your areas of weakness when it comes to understanding certain things.

This is a somewhat difficult position to possess because Mary holds her discipline in incredibly high esteem and believes that everyone needs a firm understanding of its major facts/concepts in order to make sense of the ever-intrusive role our genetic information is having on our lives.

Content Being Taught

The subject of our DNA and has infiltrated our everyday lives. Mainstream media, healthcare professionals, and insurance issues have placed the idea and science of DNA unavoidably into our thoughts and conversations. Mary has long believed that the general public needed to know more about DNA and its role in our lives and society. Though one impetus for the development of the Introductory Genetics course stemmed from her department needing to increase its undergraduate enrollment, the origins of the idea go back a long time.

> And so it's actually an idea I had talked about with my parents when my father was alive. He used to go off and give little talks for groups, a long time ago, and my mother would draw the pictures for him so he could hold them up and show them what DNA looked like. So the idea has been around for a long time and then probably about 2.5 years ago there was an article that came out in Newsweek, I think they called it DNA detectives or something, and there was a spread in the middle of Newsweek that showed the bloody walk from the OJ Simpson case, and it showed the skull and it showed a crime tape, and a gel with the DNA fluorescing and I looked at it and thought if there was any kind of hook that would get people it seems to me that this would be it – and maybe what we could do is teach something about science by using the DNA as a way to get the relevance to people.

Mary believes that DNA is intrinsically interesting and relevant to all people. She talks about how

> it's really been brought to the forefront and then it starts to seem important to people whereas before they might not have thought of science as being important. In addition to that there's a real relevance because people understand things like Alzheimer's or Parkinsons' or whatever it is, you understand that there's either a genetic connection or it's possible that science and medicine can help these people.

In addition, she views knowing about DNA and being able to use and understand its "language" as a practical necessity today, "I think there's a reason to learn it just he way you may learn counting because along the way somewhere you're going to have to balance your checkbook".

Summary

This chapter represented the settings of two science faculty teaching introductory level science courses. Using the contextual model derived by Gess-Newsome et al. (2001), I attempted to broadly explore the myriad of personal and structural factors and characteristics the make up their settings. The goal of my representations was to offer a background (Searle, 1995 from Feldman, 1997) that allows an exploration of their thinking and actions in assisted action research projects described in the next chapter.

In what ways do the characterizations made above play out in this setting? It is useful to briefly summarize the salient features of the above sections using a cross case displays. Cross case displays "enhance generalizability" (Miles & Huberman, 1994) and "deepen understanding and explanation" (Glaser & Strauss, 1970 in Miles & Huberman, 1994) that, later on, will assist me as I make assertions about the teacher change process and consider if such assertions are applicable to other settings. At this point the displays are useful to illustrate similarities and associations that the two professors share while keeping the idiosyncratic nature of their settings at the forefront.

Data displays, drawn from the explanations of the previous sections, clearly illustrate the similarities and differences in the two settings or cases (See Table 11 in Appendix I). Mary Gibson is a veteran of college science teaching and research, a full member of her scientific community of practice at the university. James Willis is gaining legitimacy in his community at the university as he works to achieve tenure. They are both, however, in a new teaching situation, that is, developing course content they have not taught before for undergraduate nonscience majors. Mary is teaching to a familiarly small number of students while Jim struggles to engage 300+ students at a time. Mary is creating a brand new course and Jim is adapting an established course to his interests and needs. Mary has surrounded herself with a co-instructor and five others who are assigned various jobs to assist in course development and implementation. Jim is sanctioned two teaching assistants who primarily focus on grading exams for their assigned section. Despite these differences, the professors share very similar expectations, feelings, and concerns about their courses (See Table 12 in Appendix I). They are both excited to teach students about their subjects and believe them to be intrinsically motivating and integral to everyday life. They perceive their primary role as teacher as "distiller" of knowledge and are concerned about making the content accessible to students' ability levels. At one level they are both developing new courses and share the concern that that effort is pulling them away from their other professorial responsibilities of research and service. Mary appears to be concerned about student passivity in her class and if they are "getting the take home message". She also struggles to keep everyone on her course "team" active and useful. Jim becomes concerned with student talking during class and wonders how bothersome it is to other students, he struggles to find the time and energy to adapt a quality course that instructs students about important concepts/facts from his interest and perspective.

In the next chapter, I describe the assisted action research projects undertaken in this project. Using the teaching as a way of being perspective, I describe the participants' action using their expectations, feelings, and concerns as a starting point. Such description allows me to seek explanation and even suggest, where applicable, multiple causes and effects of teacher action toward teacher change in these settings. Revealed in Chapter Five are the multiple tensions that exist between teachers' hopes and intentions and the choices they make in the classroom.

CHAPTER 5

THE ASSISTED ACTION RESEARCH PROJECTS

Introduction

When I was a middle school teacher I was a member of the site-based management team at my school. One of our responsibilities was to develop a mission statement. Tension mounted as our team wrangled over the language of that statement and I remember silently wondering, "Why? What is the big deal?"

Now, I am a big proponent of mission statements. I believe that they are useful tools that both create and define the hopes and goals of a particular effort. They are a self-check - a tool for reflection and critical inquiry. This became most obvious to me when I assisted in the teaching of a secondary education science methods course with my advisor. One of the students' written assignments was to define their global and curricular objectives for teaching science. Following that, each time the students turned in a lesson plan they had to include their objectives and design concomitant activities. The students struggled often to act on their intentions. I have found similar tensions as college science teachers reflect on their intentions in the backdrop of their actions.

Two patterns have emerged in my learning about K16 science teachers' global teaching objectives or "mission statements". First, most science educators share a similar intent, that is, to create a scientifically literate citizenry. Second, it seems apparent that few science educators, in retrospect, effectively act on their intentions. In essence, that is what this chapter is about. It is about mission statements and objectives (as hopes and intentions) and the tensions surrounding their effective enactment. It is about teachers acting in their teaching situations, negotiating their everyday lives of work, home, and dreams, while trying to change and improve what goes on in the classroom. And, it is a big deal.

Following the structure set up in Chapter 4, I focus on the assisted action research projects conducted in Jim and Mary's courses. I describe the questions that arose, the methods used to seek answers to the questions, and the actions taken or not taken in light of the collected data. I attempt to understand and explain the assisted action research projects using the representations of the participants presented earlier. I frame and describe the participants' actions. How I interacted with the participants is woven throughout the sections. Because this was a collaborative project, I include my evolving interpretations of the actions taking place.

A goal of this chapter is to answer my first major research question that asks, "How does placing the professor in a position to conduct an assisted action research project help to foster teacher change conditions?" Although the methodology section generally outlines the study, it may be helpful to the reader if, at this point, I describe how the participants and I conducted the projects.

Phase I of my study sought to understand the lived experiences of the participants. For a month I attended classes, interviewed and conversed with students and professors, analyzed a faculty and student survey, and reviewed course materials. Following that I held a Phase I meeting with the each professor to discuss our initial observations about the course. During the , meeting I became a *facilitator* with the goal of "construct[ing] a supportive and safe normative environment with [the participants to] help them explore issues with their own vocabulary, their own metaphors, and their own ideas" (Carspecken, 1996, p.155). I presented written documents summarizing my collected data and the professors talked about how they were feeling about the students, the content, and the flow of the course in general. In the end, we agreed upon a question or two that should be investigated and determined a means to collect the necessary data. Following McKernan (1988, p. 173) we attempted to "to solve immediate problems" and "[feed] the practical judgment of actors in problem situations."

The articulation of our starting point questions launched us into Phase II of my research study, the assisted action research projects. Once Phase II began the research study as a whole became somewhat ad hoc. Although I continued to observe classes and collect field notes other data sources emerged. I met with professors as needed in their offices, meeting rooms, classrooms, and, with Mary and Liza, at restaurants. I interviewed, emailed, or called students at the beginning and end of this phase to collect data. Sometimes a student and I would chat on her way to a next class. I emailed teaching assistants and informally interviewed another faculty member of Jim's department. Throughout all of this, I carefully tracked our questions and actions in hopes of understanding how or if an assisted action research project, with me acting as knowledgeable other and critical friend, could promote teacher change toward an inclusive pedagogy.

Below are the descriptions of the assisted action research project. The cases are described, by and large, chronologically and in great detail. My interpretations of the projects as they unfolded are embedded in the descriptions. I believe that I came to understand elements of Jim's and Mary's ways of being as teachers through this study. I experienced and helped shape their wisdom-in-practice following Feldman's (1997) position that "... for others to fully appreciate [a teacher's wisdom-of-practice], they need to somehow move into the situation with the teacher and students, and to interpret it, allowing their interactions to shape the ways that they understnd the situation, and then allowing the new understanding to shape their interactions" (p. 770). Jim's project description precedes Mary's and a chapter summary follows.

Jim's Project

Jim is a person who creates an aura of calmness and control when you are with him. I've felt it in our face-to-face meetings and while he taught, spoke on the phone, or interacted with colleagues. As such, his telling me that he was overwhelmed and stressed at times, confounded me. I bring this up because it highlights my growing realization that that I really didn't understand how thinly he was stretched during our project. He didn't really let that be known. Perhaps he is just "that way" – one of those people who cannot dwell on or complain a lot about tough situations. Or perhaps our relationship didn't warrant such disclosure. Or perhaps it is because he is male and a scientist and in our society that may mean you trust that your individual inner fortitude will see you through. Perhaps too his efforts are simply those of a junior faculty member working hard to meet personal, departmental, and university expectations.

I bring this up as an introduction to his assisted action research project for three reasons. First, although I don't believe I understood *how* overwhelmed Jim was I knew his time was very tight and that made me incredibly grateful that he agreed to continue working with me. Second, mindful of his situation, I did not assume as critical a perspective on issues of teaching and learning as I had anticipated. Third, it took me some time to realize that the work of science education researchers, feminist theorists, and my own past research on student learning in the Introduction to the Earth's Oceans course was novel discourse for him.

The Introduction to the Earth's Oceans course was well established and organized when Jim became its instructor. Powerpoint lecture presentations were available from other professors, activities were established in the required student workbook, and exams were written. At the start of the semester, Jim presumed he would change the course slightly to meet his needs and interests but that the logistics of teaching to over 600 students would be his greatest challenge. As a result of our work together, however, other issues emerged for him. Tensions coalesced. After completing the faculty survey, he expressed interest and bewilderment over how nature of science, gender, and equity issues should be dealt with in the classroom. During an early conversation he asked, "How do you make [the course] more interesting to females? How you get more females to want to be involved in science?" (notes, Phase I). These questions set the tone for our dabbling into issues of curricular and teaching transformation toward a more inclusive pedagogy. Throughout the project, our conversations meandered through Rosser's first two stages of curriculum transformation (Rosser, 1997). From the start of the project, however, the more pragmatic problem of student talking was of greatest importance to Jim;

> One thing that has come up is that students, some students, talk throughout the lectures in this course. It's become a real problem according to [the other professors]. It gets very rude. So, how can I keep students from talking during lectures? [The other professors] have put together a contract for the students that addresses this so I'll probably use that to let the students know what is not okay. (Jim, pre-course initial interview)

The issue of student talking during lecture became a major focus of the assisted action research project. In the role of critical friend, I attempted to broaden Jim's focus and endeavored to infuse issues related to feminist critiques of science and transformative practice while at the same time allowing his "immediate problem situations" to guide action.

<u>Phase I Data Summaries: Considering starting points</u>

At our Phase I meeting held one month into the semester, I presented Jim with summary notes from a student survey, student interviews, and my observation notes. He, in turn, reflected on teaching the course thus far and how it meshed with his other responsibilities. Together we reviewed the Phase I data, I with a critical perspective and Jim with one that was more pragmatic. He sought my advice, respected my ideas, and together we determined a plan of action toward mediating the talking issue. Below I summarize the data that was presented during our Phase I meeting. I explain the findings presented from the student survey, student interviews, field notes, and classroom observations.

The Phase I student questionnaire data revealed student demographics and students' thoughts and attitudes about science and the course specifically. Presenting findings from the survey began my attempt to bridge the gap between who the students were (their interests and goals) and how the instructor thought about them. I wanted Jim to see his students as a group of individuals who, by and large, shared an interest in his course, yet came from different and mostly non-science backgrounds. I hoped that this would enable us to begin exploring ways to make the course more relevant to the students' everyday and future lives.

Two hundred and thirty-five students (one hundred and fifty three females and eighty-two males) from the first section class completed the questionnaire. Ninety percent of the responders were Caucasian, two percent were African-American, two percent were Hispanic, four percent Asian/Pacific Islander, less than 1 percent was Native American and one percent was mixed ethnicity. The majority of the students were freshmen (90%) and non-science majors. Sixty-nine percent of the students reported taking the course solely because it fulfilled a general education requirement. Almost 20% of the students were undeclared or unsure about their major.

The survey implies some interesting inconsistencies in student understanding about the course and its related science (See Table 13 in Appendix I). For example, the majority of students don't agree that what they will learn in the course can be applied to everyday life or careers yet agree that oceans impact their lives and they should learn about them. They also tended to agree it is useful to understand how scientists think and solve problems. The majority of students agreed that climate change is an important issue. While the majority had never considered majoring in science they believe that professors would assist and support them if they did and agreed that males and females can succeed equally well in science. Finally, the majority holds a positive, non-critical image of the beneficialness of science to all people. This data suggests that clear and concrete connections between course topics and students lives is necessary for student understanding of the widespread and varied ways the oceans impact our existence. It also echoes a cultural belief of the goodness and value of science.

Females and male responses on the survey varied on a few statements. For discussion purposes, I highlighted survey statements that showed differences of around ten or more percent between females and males. In general, females seemed to agree that learning about the oceans, and especially climate change, was important to them perhaps as individuals but it wasn't necessary for everyone. The survey indicates that more females than males may have difficulty believing that they will use scientific concepts or thinking in their everyday and future lives. This agrees with much of the data I've collected from females in this class in the past, that they express interest in the class but do not believe or expect that it could/should be relevant to their lives (Weiss, 2001). As a group, more females were not sure or disagreed that they were good at math than agreed. However, many don't agree or are not sure if being good at math is a prerequisite for being good in science.

The survey also allowed me to present a preliminary overview of the majors in the course. I had hoped the list might trigger some discussion about how to enhance the content to give it more direct relevancy to students' everyday and future lives. Jim found the list interesting but at that time we did not discuss substantive content changes to the course. Following this summary from the Phase I student survey, I highlighted themes emerging from early analysis of the student interviews I was conducting.

Students volunteered to be interviewed by marking a box at the bottom of the student survey passed out in class. Of the hundred volunteers, I selected participants from as varied a background as was possible in the short amount of time that I had to make contact. I particularly sought to interview a few students who expressed interest in teaching and those that were undeclared. This was because the Collaborative's major purpose was to improve the education of preservice teachers and increase student interest in the sciences. In addition, I tried to include students of color in my selection (no Hispanic students volunteered to be interviewed). Out of twenty-five phone calls to potential participants, fourteen students (ten women and four men) agreed to be interviewed (See Table 14 in Appendix I). Ten of the students were Caucasian and five were students of color. While the majority of students were freshmen (nine) and white (ten), they varied in major (undeclared, German, business, journalism, psychology, history, education, communications, sociology, hotel/restaurant management, English). They also represented a wide range of clubs and interests and sports teams. One student, Roger, was on football scholarship, Sierra was a cheerleader, Zac played in the jazz band and was hoping to double major in English and music. Lisa, an English/Education major was in the Science Fiction Club. Sophie was madly working to complete her senior thesis in sociology.

Students were interviewed for forty-five minutes about their background, experience in science courses, and thoughts about the course under study. I paid the students for their time. From the interviews, I hoped to gain broader understanding about the activity I witnessed in class and the student survey responses. Because the students represented such a small percentage of the students in the course I considered them “ambassadors”, individuals who could attempt to speak for their population and offer explanations for my initial findings. In addition, by giving students opportunity to talk about the course I hoped they might raise issues and ideas that had not been raised elsewhere in my data sources.

The students had much to say about the course and its professor. My goal in sharing this data with Jim was to present it with as little interpretation as possible. I hoped to motivate his thinking and action on the students' ideas rather than lead him into action based on my analysis.

Most of the student interviewees had never met Jim. In general, they came to class, took notes, turned in assignments when required, and left. They rarely communicated with Jim or the teaching assistants concerning issues or questions they had about the course content. In fact, only one student, Zac, said he asked questions during class about the topics being covered while Gwyn was observed asking questions about logistical issues such as test format and location. Luon and Alex both had met with Jim at the beginning of the semester when he helped them get into his over-enrolled course.

During the interviews, I asked students to talk about the various components of the course from a perspective of what was helping them or impeding their learning. Many were intrigued that I would explain their ideas to the professor. For example, Melissa, a freshman struggling with the course commented to me, “So, you’re going to tell him these things, that’s great!” Not surprisingly, no student had ever considered telling the professor her impressions of the course.

Student interviews were aimed at understanding the students’ backgrounds and interests in science as well as their thoughts about the course. In general, students offered praises and criticisms related to various components of the course, namely, the professor, exams, lectures, Powerpoint presentations, textbook, workbook, group work, note-taking, teaching assistants and student talking. Many students also talked about broader issues related to schooling and their own experiences, for example, general education classes, science teachers, math, course relevancy, and science interest.

I chose to highlight student thinking on five areas that the majority of students agreed about as a way to introduce their voice into the aAR projects ; 1) the power point presentations were beneficial, 2) Powerpoint slides change too fast, 3) workbook is useful study guide, 4) group work is beneficial both in class and during exams, 5) students expected to learn more marine biology. Of course, these are broad characterizations of the student responses and during our discussion I attempted to show the range of responses. For example, two students, felt that Jim repeated himself too much during Powerpoint presentations and they did not share the note-copying angst of their peers. This angst manifested itself in the majority of the students commenting that he put too much information on the slides and changed slides too fast. Although the students, over time, realized that the same information was in their workbook they still chose to write down every word off the slides because it helped them remember it better for the exams. And while all the students felt that group work was ultimately a beneficial activity during class and exams, four students did not understand its ultimate purpose. Eight of the interviewees commented that they were surprised at the course content and a few, with some embarrassment, confessed that they had thought they would be learning more about whales and dolphins. Below I offer five student quotes that epitomize the interviewees thinking on these topics.

> (Luon, sophomore HRTA major, speaking about taking a group exam) I think it was interesting because I never had that kind of exam before. And some part I think I like it because you can just talk to people and I think easier given that if, let's say you have final and you have to take like all - some take like at the end - then make it easier like to memorize like this is something that we talked in the class and discussed in the class – that is good – but [only] some part of it - so why you have to go do [the exam again with] like group - I don't really – I could not get that -- I don't know what the purpose of it is for...

> (Cindy, freshman, undeclared, speaking about difficulty of first exam) Well in the first exam I just – I had fallen behind like on the readings and so it was my own fault I think for not doing well... but so I felt like OK I did OK and ended up getting a C. So, I did all right but I, like, I know I could have done better and it was - I was just frustrated because, like, one of my friends was like blaming the professor. I wasn't putting the blame on anyone but I knew if I had just like kept up the reading and tried to keep up with him. So like this time around for the second exam I am like writing really fast, like trying to keep up with him and then I would go back to my dorm and then type up the notes to make it look more clear because my writing was so messy and so I am going to try it this time around to see if I could do better by like trying. I have an OK feeling coming out ... like I liked how ... after the exam you got to do the group exam but then I knew that I could have done better if... you know stuff like that.

> (Zac, freshman English major, speaking about workbook group activities) I have a few friends in the class – so it is nice to be able to talk somebody else and get another opinion on different things and some times if we are doing something that I don't understand really well and the person next to me gets it better than I do. It always helps out to say this is how I did it – this is how they did it and what works for either of us. And how do we get the right answer. I like that.

> (Sierra, freshman undeclared major, speaking about the Powerpoint presentations) I like the Powerpoint, a lot of my professors actually do that. I like it because it gives you pictures and stuff and diagrams rather than my women's studies teacher who just talks so you're not really sure what you're supposed to write down. But he has it all planned out which is good.

> (Roger, freshman, undeclared, football scholarship awardee, talking about the pace/content of lecture) I mean I just can't understand a word he's saying – my level was down here and he started up here and I had to catch up. But this guy, his notes are too fast. He puts stuff on the board for not even 30 seconds and it's hard to copy them down and thinking them- and then I don't have the notes to study... he just kind of babble on down there ripping through those notes and there's no reason to even try to copy it down because he's gonna switch it. And it was more interesting in microbiology – it was about cancer and aids stuff that really affected me. Whereas, to tell you the truth, I could care less about the ocean and why it's salty - it's really not gonna affect me. It's kind of hard learning about that...and the stuff that you try to learn really has nothing to do with you so, I have to do it but...

(Melissa, freshman, undeclared, talking about her course content expectations) I thought oceanography was going to be about whales and stuff – I don't' know why but that's what I thought so I was kind of like shocked – I don't know why I even thought that.

Four students made unsolicited comments about student talking during lecture and I paraphrased their comments for Jim. One student, Ellen, felt bad for the professor when all the students talked and she explained how there was a lot of rude talking in her other general education classes too. Zac stated that the talkers sit in the back of room and drive him crazy so now he sits in the front. Alex, a junior German major, and Carly, a freshman business major, felt that it was hard to learn in a large lecture with students talking around you. All of these students stated or implied that talking in large lecture classes was "just the way it is" and that there was very little that they or the professor could do about it.

My Phase I summary also included notes from nine classroom observations. I had utilized an open-ended observation protocol that attempted to capture the organization of class time, concepts covered during lecture, interaction between setting participants, and the activity and character of the participants during class. Organizing my observational notes for this meeting was challenging as I waffled between suggestions for course improvement and merely presenting data. I had collected data about, for example, the number of questions asked during lecture, wait time, slides presented, topics covered, professor-student interactions and the time spent on various classroom activities (announcements, introduction, review, lecture, workbook activity, closing comments). I chose to combine the two perspectives. To prepare, I coded the observations using Atlas.ti analysis software and printed out grouped queries from three codes; professor questioning, student activity, and TW comments (my personal comments and questions bracketed in my observation notes).

First, we discussed more quantitative elements of the class, for example, how his numbers of questions asked ranged from one to twenty-seven questions per class and that student questions/comments ranged from one to eight. Wait time was less than a second in most cases and students spent from six to fourteen minutes on the four group workbook activities utilized. I explained how, in my opinion, the presentations were colorful, clear and concise, and easily visible from all parts of the lecture hall. I combined a more critical perspective into our discussion by explaining that student talking increased when he changed slides quickly or when the slides had "too many words to write down" (student comment during lecture). I noted a mismatch between his appeal to students to sit back and listen because "the notes are in your workbook" and students' continual note-taking frenzy. I also asked rhetorical questions such as; could the presentations include more real images of the topics being covered? Are films available? Can the professor's research interests be integrated into the lecture topics? Is there any potential to bring in samples for students to pass around to give the class a "hands on" component? These questions stemmed from comment notes I had written during the lectures and many were echoed in the comments made by students during interviews.

Of course, the presentation of the Phase I data was not always so compartmentalized. In our discussion, I drew upon data from all the resources to raise issues better. For example, the issue came up during my interviews that students wanted more opportunities to interact during class. Some were frustrated that they spent so much of class-time hurrying to copy down notes. Some students felt the class was too dull and needed more interactions. Jim had remarked that he wanted students to be thinking about the information during class and not just copying notes. This was apparent in the questions he posed during lecture such as "Why does the continental crust rise higher than oceanic crust?" or "There are places not in isostatic equilibrium, can you see any on this diagram?" In both cases, however, there were no responses from students. Jim also commented that expecting students to talk in a large lecture wasn't realistic because it was too hard for them to do. I commented on the difficulty of thinking about a response to a professor's queries when discussion is not afforded in some way. My observations revealed that the in-class cooperative group activities were used infrequently. Jim explained how he was having a difficult time fitting in the group exercises with his content focus.

Our time for the Phase I meeting was shorter than needed. Jim had time commitments squeezing all his meetings. The effect of that was that I gave him the raw data from the coding queries I had generated about his in-class questions and my class comments for his perusal. The time situation intensified a growing dilemma I was facing as we discussed the class – how critical and "knowledgeable" should I be? Jim was in a unique situation (that he recognized) of not having the time or energy to make all the changes he would like to the course. So, the question for me became, how much do I throw at him all at once?

During our Phase I meeting, I came to realize that my feminist perspective on teaching and learning required a transformation of thought and action that was not likely to manifest itself in this classroom at this time. And so I chose to not bring up observational comments such as, "in future lectures he should make explicit connections to the expected careers and interests expressed by students in the course", "does he know what students already know about these topics, what do the MA frameworks expect that they know by now?", "he puts up diagrams and says, 'you can see here that the…', yet I don't think students always see what he sees", "can't he use headings from newspapers and magazines to show the relevancy of these topics, what would it take clear up the disconnect I feel is going on?", "why must they know all this terminology?", "does the TA do anything to support him in class?", "students need more time to discuss these topics", "why doesn't he migrate through the lecture hall during the activities?". And I believe that withholding those comments at that time was the right decision, because this was to be *his* action research project. I needed to understand his perspective and the situated supports and constraints to his practice (McKernan, 1988). I needed to accept where we were on Rosser's stages of curriculum transformation and that this was just the beginning.

<u>Choosing a Starting Point</u>

At the beginning of the Phase I meeting Jim said

> Second section is so noisy and so, really, one of the students that came in to office hours yesterday said, because he's in the 2nd session, he said, "I can totally see you just get bummed out by people not really caring about it's obvious that you really care a lot about". And that was a great complement. It's great that they see that I'm into it and I think it's cool stuff and I really want them to get some of this really neat basic oceanography and I'll just keep hammering certain points to make sure they get it because I think it's so cool when you start to understand how the winds work and how the oceans flow. This young guy picked up on that and said, Yeah, I could see the wind go out of your sails when you have to stop, people are in the back talking". But it kind of gave me some perspective because I think he's an upper classman and he's been in the UMASS system and in a lot of big classes, he said, "I think you're much too nice."
>
> What I do is to just stop lecturing when they get going, I just wait. It's really frustrating. I may just go up to the students who talk at the end of class and tell them they've got to stop – they can't keep doing this.

As a result of his identification of "student talking" being a serious and immediate problem it became a starting point for the action research project at our Phase I meeting. Jim verbalized the problem this way;

> I guess I'm interested in knowing more about the talking issue, and if it's bothering other students or if it's not an issue for them as it is for me. Is it affecting learning? Am I losing respect for not getting down on those students? Is it hurting the class in any way? Should I stop talking? Should I talk to the students before class? ...And this writing everything down issue!?... I'll work on the lectures around that.

My field and meeting notes recognized student talking as an issue as well;

> ... he waits for students to quiet down before lecturing, he sits on the stage waiting and watching the students (Phase I observation notes 2/21)

> Jim is feeling very overwhelmed. He talked about his teaching load of four courses, his research, a conference he is planning for spring, and publications he should be revising for Nature. Plus the students in section 2 of the Oceans course are being difficult with their talking. (Phase I meeting notes)

I have to admit, I was at times more worried about how the talking issue was affecting Jim than his students. He was not used to dealing with this kind of student belligerence. The reality that students could be so rude and that, for example, one "big guy in the back" stared him down after being asked to stop talking was incredibly frustrating for Jim. We talked about the situation. I wondered if perhaps the student activity should occur at the end of class when talking became most elevated. I suggested that the lecture hall was darkened too soon before he began his presentations resulting in many students not realizing he was waiting to start class. I asked him if the notes should be on-line, if that would keep some of the talkers away and if the workbook exercises were doing "too good" a job keeping everyone coming to class. To the latter comment he remarked;

> Well this is something that has been brought up. It's great because the workbook keeps attendance high, and it's terrible because it keeps attendance high – is the way that somebody put it. But I'd still rather deal with a little bit of rowdiness and have a full classroom. Because even the kids that are talking are going to get something out of it. I mean it's hard on me, true, but it's okay.

There were other suggestions I could have made regarding the talking issue that I chose to forego. I wasn't sure if it was the right time. As I have pointed out, this was an intense semester for Jim and though he was committed to teaching the course effectively he also needed to survive teaching it. So, for example, I didn't mention how he rarely smiled or walked the isles during lecture or activities. I didn't emphasize my summary notes about wait time being non-existent or that, in his effort to present information clearly students became passive receivers of information, unable and unwilling to answer or ask questions. I felt a tension mounting, for him, me and some of the students, regarding the role of class time and the lack of student participation.

During Phase I, Jim reported that he had decided to work on the course only on Tuesdays and Thursdays because he needed to "set some boundaries". This comment highlighted another problem that had emerged for him; time management. I asked Jim why he wasn't simply using the existing Powerpoint presentations and exams and he explained that the other professors covered material faster than he did and that there were topics that he wanted to cover in more depth. Jim wanted to make the course his own. He could not simply teach the course "ready-made" and so he consigned himself to developing the course as he taught it. Unfortunately, the constraints of time impeded our investigation into this issue as part of the project. I would have liked to discuss issues of lesson planning and student activity with Jim as a way to help him plan. Instead, we talked of specific ways he could change his teaching, such as creating his own group work activities using the blank sheets in the student workbook. The broader issues of curriculum planning and implementation did not become a substantive part of our study.

Phase II: Action Plan and Outcomes

Jim took action to change aspects of his teaching throughout the semester. Besides noting a deeper understanding of the issues surrounding his course and students, he made overt changes to what he did in class. These changes manifested themselves in how he delivered content knowledge to the students while the main focus of the content remained the same.

My activity in the project did not change. We agreed that I would continue observing classes and take notes that focused on his interactions with students and my questions/suggestions about particular aspects of the lecture. I would also email students with some questions and interview them again at the end of the semester. Toward the middle of the semester, I contacted the teaching assistants through email asking them of their roles and the types of interactions with students. They informed me, through email, that their primary responsibilities were to grade workbook activities and assist with exam proctoring/grading. They had each interacted with less than ten students to clear up problems with grades.

With regards to the student talking issue, however, Jim and I needed another way to gather information. The nature of Jim's questions about talking in class was student-oriented and thus we needed their input. At the Phase I meeting we discussed the many ways we could get at student thinking on this issue. I explained to Jim how 2 + 2 feedback works and he was interested in gaining data of that type. We wanted the data from both sections of his course. He explained that he would be conducting a review session in a few days that included students from both sections. Below is a section of our Phase I meeting where we discussed collecting this data.

> Tarin: I'd like to ask a larger group of students their ideas on this – maybe as a free response situation – but I don't want to use up too much in-class time – and would want comments from both sections.
>
> Jim: You could do it at the review session next week because it gets a lot of students and they're from both groups –
>
> Tarin: What night? My husband is out of town the middle of the week and I think the sessions run late right?
>
> Jim: Well, why don't I just ask them to do it?
>
> Tarin: That would be great – you could do that? Okay. Let's make it short and simple, if you could ask them to explain one thing that is going well in the course and one thing that they would like to see changed –
>
> Jim: Let me get this down –
>
> Tarin: You could just put it up on the overhead –
>
> Jim: Yeah, I'll do it right at the beginning. No problem. Great. I'll get some idea if the talking is an issue that way.

By agreeing to conduct this important piece data collection Jim was interacting with students on a completely different level than he had before. He was asking for their opinions and ideas on issues that were not solely content related. I felt at the time that this small act was a big step toward sharing power with his students.

On the day I collected the one hundred and forty-two feedback sheets from Jim he commented;

> This was interesting. Some students were surprised I wanted their ideas – there's even a letter in here written from someone who's not in my class but came with a friend. She wrote how cool she thought it was that I did this. I perused them, they think I go too fast, want easier exams, etc. ...a few commented about the talking, not too many I think. You'll have to let me know what the gist of it all is. It was interesting.

Within a few days I emailed Jim a summary of the students' comments. The majority of students commented on the Powerpoint and lecture structure, talking during lecture, note-taking, exam difficulty, group exam structure, workbook, group activities, and review session worthiness. A few commented more personally about the professor. In a phone conversation, I asked Jim if he felt that reading these comments helped him get to know the students a little better. He agreed that it had. In general, the 1 + 1 student evaluations further motivated Jim to make three major changes to his teaching of the course; 1) recognizing student opinions on talking in class, 2) simplify the Powerpoint presentations, and 3) modify exam questions. He made these changes because he really wanted to show students that their voice was being taken seriously.

These changes began immediately following his receiving of the 1 + 1 summary. Right away, Jim embedded the student quotes about talking into the first part of his Powerpoint presentation. One by one, in a light but serious tone, he pulled up the students' quotes. In a phone conversation following this presentation, he said that now he had students backing up his demand for the rude talking to stop. He used their quotes for that reason but also to let students know that their "voice was being taken seriously." Jim felt that their quotes effectively demonstrated that talking *was* an issue for the students and something had to change. For one, he hoped that the students would be more aware of their impact on their peers.

In addition, Jim was beginning to think that class length was "really bogging down the students" and increasing their likelihood of talking. He developed a strategy to help ameliorate the situation. He informed students that they would be dismissed from class early if he "got through" all of his slides. It was, after all, spring and the warm weather was definitely beckoning the students. A week after introducing this idea he felt that student talking was less during class, or at least they were quieting down faster. He reported that one day section one was released from class fifteen minutes early while the other section stayed for the full seventy-five minutes. Over time, however, the strategy lost its effectiveness. Jim planned lectures that ran longer than he anticipated and even when students were attentive it was rare that they were released more than five minutes early from class.

Jim also began changing his Powerpoint lectures in response to the student feedback sheets. His hope was to not "cram every lecture with information" and "to be pickier" about the content. For example, he described how he took out content on sea ice formation and its related workbook activity. In fact, he began eliminating workbook activities more frequently, completing about four between exams and assigning some for homework. He began using more images and short video clips in his lectures. Jim also experimented with creating his own activities that better matched his content focus. For example, he asked students to use a blank sheet from their workbook and create a diagram of the earth, its latitude lines, and global wind patterns.

Over time these changes became more and more evident. Jim included fewer words in his Powerpoint presentations. He went slower during lecture and made a point to wait for students to copy down notes. He would often ask the students, "Is everyone set with this? I'm going to go on now." The following quotes reflect student impressions of these changes;

> He has slowed down a lot which is better because it's so much easier to take notes when you can concentrate on one subject for more than 30 seconds because obviously he knows he just whips through it. He's gotten a lot better at that... (Sierra, Phase II interview)

> Yeah, it's not so hard to keep up – he waits and all. Actually, sometimes we wait too long. But overall it's much easier to get all the notes. (Eric, Phase II interview)

> He does go slower now. But I didn't think it was a problem before... (Kate, Phase II interview)

My field notes captured the change as well.

> Jim has changed his slides a lot. They have highlighted statements on them and many images. He even put up an "old" slide and lamented that, "Oh, I shouldn't have put that up, now you have to write it all down." He has commented more than once that he does not want them to worry about the details but that he wants them to get the big concepts. I am amazed at this change from the early lectures that were full of words and fewer

images and more time spent on the details of a vocabulary word. Oddly, I even feel a bit worried about this change, is this okay? Are the students getting enough information? To see it happen, even though I know theoretically it's the right track to take, it is a bit unsettling for some reason... (3/26 field notes)

Jim changed his exams. The exams in this class are traditionally twenty-five question multiple choice bubble sheet type of assessments. During our Phase I meeting he had commented;

> The exam was a little too hard, the first exam. It was. They don't think, they thought it was too hard for a 100 level gen ed course....it was just a few percentage points below a typical Ed or a typical Martin exam. I'll maybe make it a touch more straightforward on the next exam... [The students] didn't read the questions – when there are only 20 questions I really try to fit as much content into those questions as I could. That could be construed as being tricky – but I just, you really had to evaluate every one of those options because every one of them was meaningful. I didn't have a lot of just nonsense answers for them to discount they had to really think about each one. And in an exam like that you really have to stay focused. 70s may be a little low as a class average.

Melissa agreed, capturing the feeling of about half of my interviewees;

> I think the exam was hard sort of – my roommate thought it was really hard and I'm like, I thought it was hard - just the way the questions were worded it was just not what I studied. Well it's what I studied but it wasn't what I was expecting. The way the questions, they were not on what we studied – I don't know. I got confused with the way it was all worded. I studied for awhile.

The 1 + 1 evaluations spurred changes to the exam questions. After his quick perusal of the evaluations he emailed me saying, "[They think] exams in general are too hard." So he changed the questions. He reported that in a few places he added nonsensical answers to the multiple choice options and asked "simpler" questions. On the first exam, students were expected to define, interpret, and apply vocabulary or concepts within one question in order to choose a correct answer. Jim broke up those questions, allowing students to define in one question and interpret/apply in another. He also used fewer graphs and diagrams within questions. For example, on the first exam, nine out of twenty-four questions asked students to interpret information from diagrams or graphs whereas only six out of on thirty questions on the final exam did the same.

Jim also began developing review sheets before the exams. Initially he had the sheets available to students at the review sessions and later he posted them on the course website. A few students from my interview group emailed me comments related to the exams and review sheets. Cindy wrote, "I can now study better and it makes it easier to prepare for the exams." Melissa wrote, "The topics seem a little easier to understand now... The reviews are helpful for what will be on the tests." Pam also appreciated the review sheets, writing that, "...the Study Guide has helped me on the exams."

All these changes appeared to make a difference grade-wise. Student average on the second exam was almost a full grade higher than on the first. Jim's students' exam grade averages were now more on par with the previous semesters' averages.

<u>The Project's Final Weeks</u>

As I read back over the nine meetings and/or correspondences I had with Jim in the last six weeks of the semester a pattern of support emerged. During most of our interactions I was either thanking him (again) for allowing me to research his teaching, supporting his efforts, or recognizing his strain. My field notes are replete with remarks such as, "He is trying so hard!", "He's so stressed...", and "He's got a lot going on." In emails or during discussions I would make comments like, "Thanks for all the work you are allowing me to do on this class – it is great stuff and you are doing a great job!" or "I want you to know how much I appreciate you allowing me to do this work in your course in the midst of your deadlines and other responsibilities – I hope that, in the end, you come away with some better understanding of yourself as an educator and what is and is not possible with these students within the context of your setting." I supported his efforts by relaying information like, "...if you can get two cheerleaders to discuss the coriolis effect on the beach in Florida – well, you must be on to something, right?!" and "Here's another great quote [from a student] I thought you might enjoy."

I include this realization because it highlights how overburdened Jim was at the end of that semester and my attempts to acknowledge his workload. I became less critical and more supportive. I realized that there was only so much that could change in a semester and particularly in this situation. I did, however, infuse two more sets of "data" into the project as "food for thought".

In the original class survey I had asked students for information about their majors and the careers they hoped to hold in the future. I was interested in this data because, from a feminist perspective, knowing more about the students and their interests was an important step toward connecting with students' lives and interests. In early April, I emailed a summary of this information to Jim hoping that we could discuss it. I found the list compelling. It offered character to the nameless sea of faces that stared up at Jim as he lectured. It had to the potential to act as a catalyst for change if connections could be found and/or designed into the curriculum.

Jim appreciated the list. In a hurried exchange before class he thanked me for it and said he hoped we could discuss it. I, however, decided not to schedule the meeting. It seemed to me that such a discussion was not, at this time, a reasonable expectation. He spent all of his available course time preparing for the next class – asking him now to spend time to exploring how he could change specific lessons that he might teach semesters from now seemed untimely. I decided instead to continue to observe classes and interview students till the semester ended and not expect him to consider new issues. That idea worked for about a week.

It was a warm day in late April. Jim had created an interesting lecture about wave speed using wonderful images and actual slides of tsunamis chasing people up a shoreline. In the final 10 minutes of class, students began talking and some of the effect of the images was lost. As I listened to his lecture I kept re-organizing it in my notes. I scribbled questions throughout the lecture such as; Why not show the tsunami slides first? Why not ask students what this is and why it happens. Why not plot on a map the location of tsunamis and their effect on major cities/tourist areas/business centers? Why not consider their impact on communities and individuals? Why not consider the social status of the people most affected by tsunami's today? Why give them the wave speed equation – can't they figure it out? Haven't they used distance = speed x time throughout secondary school and when they drive anywhere? Where are tsunamis happening today? Where are the headlines from affected countries? Where is the on-line data arriving every minute that tracks small waves moving briskly across the open ocean?

As three hundred students filed out of lecture that day and another three hundred instantly began filing in I met with Jim. For the next fifteen minutes we went through my notes and his Powerpoint slides. I posed my questions and suggested changes here and there. I explained where I had gotten lost or why a diagram was confusing. There was not much time for this discussion, Jim followed along patiently, thanked me, and I left. I don't know if he actually modified anything in his next lecture - I didn't really expect him to. I did though, want him to consider my questions and ideas and I believe he did. It spoke volumes about him as a teacher that, in the midst of that setting, he could focus on teaching and learning for that fifteen minutes.

As mentioned earlier, the rude talking crept back into the background of Jim's lectures. By mid-April he was once again pausing during lecture and waiting for students to quiet down. The promise to be dismissed early hadn't occurred consistently, the sun was shining, the lecture hall stuffy, and students were antsy. Jim lured students to listen with comments like, "Listen up! This next point will be on the next exam!", "You're not going to get all this and it's important for the exam.", and "It's ashame you're going to miss this, it's really cool and you'll be tested on it!". Once or twice he just gave up and told the students to leave.

My student interviewees appreciated Jim's efforts to create a quieter lecture hall. For some, his efforts were effective while others were still frustrated. Others still saw no hope for change. An email correspondence to them in April resulted in the following student comments on the issue;

> …the professor has cracked down on the noise and made the room a better learning environment. (Zac)

> The lectures are so long, sometimes my friends and I have to talk to just to move around and keep awake. (Tom)

> …one thing that was impeding not only mine but everyone's' learning is that he's started to wait till everyone's completely silent or he won't teach, we didn't get to two slides we were supposed to have the class before the test because he was waiting. (Sierra)

> I just wish that the professor would handle the talking issue in a different manner. Even though I hear that the other section (section 2) is worse it still bothers me… Now I know that it is not his fault that people are talking, but I found it unfair for the people that weren't talking. (Cindy)

> I am not exactly sure how he should deal with the talking issue. I just wish he could find a better approach because the "talkers" don't feel bad for the students who actually want to listen. They want to get let out early so by the professor letting us out due to talkers only makes them more apt to disrupt the class. I suppose he could try kicking the constant talkers out, but that would be hard for him since the class is so big. So I am not really sure what a good solution would be to this issue... (Kate)

The only thing that is impeding my learning are the other really immature students in the class that talk ALL the time... (Sophie)

It's rotten that those kids talk so much. He can't do much about it. (Alex)

During a brief meeting in his office in mid-April I asked Jim what he thought about the talking issue. His answer surprised me but made sense. He explained that, because he was so stressed, the talking wasn't getting to him as much – he just didn't have the energy to worry about it. He believed that the students could only handle class for a certain amount of time and adjusted his lectures to be a little shorter. His focus was to get through the lecture. He also said that he didn't feel that the talking was bad all the time and found that the students were policing themselves more.

Jim and I met for a Phase II interview in late April. Our talk focused on issues of relevancy, gatekeeping in science, and teacher change. The transcript of the interview reflects, unfortunately, that I did most of the talking on these topics. He reiterated his goal of teaching students the science of oceanography, explaining how they were learning, "...all the fundamentals. And it's the real deal...". I offered examples of how, using a case study approach, the science could be embedded into more relevant scenarios and explained that:

> One of the big issues is that students who don't see themselves as scientists, never see themselves as scientists, never get put in a place where their identity allows them to think that way or understand why it's useful. Students in high school see themselves as jocks or music people or smart kids, they aren't put in the place where they see themselves as potential scientists or mathematicians. One of the urgings is to have curriculum offer them chances to experience those roles in ways that connects to who they are, who they want to be.

I also presented and explained to Jim Dr. Kathleen Davis' model of Legitimate Participation in a Community of Practice (Davis, 2001). Mostly I talked and he listened. I explained that "I see a course like this potentially opening the door and giving students access to this community". Jim agreed, saying, "I think that's definitely a big deficiency in the course... that there is a big disconnect between the way that I would love to see them be able to think and problem solve and the way that the course is laid out." He then told me a story of one of his honors students switching her major from the social sciences to oceanography and of a doctoral student who became interested in geology after her undergraduate degree was completed. He asked, "So how, in a course like this, considering the material that I cover, what could I do to address this gender issue which is – what could you see?" And said:

> But I've never gone out of my way to – I've really made it more of a non-issue – I'm just going to do the best I can at getting the information out there and I never really thought that gee, in this lecture I should talk about the contributions of women in oceanography specifically or – and I don't know if, maybe I should be doing that –

We talked about workbook exercises changing to meet his interests for the students and also being relevant to the students' future lives and careers and I supported his efforts to teach students the fundamentals of his discipline. He lamented on students' disinterest in completing the readings and their inability to "stick out" the lectures. We also discussed the external constraints to developing and implementing such a student-centered focus: time and departmental expectations about how he should spend him time.

In the final weeks of the semester, I began collecting my end-of-the-semester data from the students. First, I scheduled student interviews. All of my original interviewees could talk to me again except for Roger who, because of a new football workout schedule, could not fit in a discussion. For this interview, I wanted the students to discuss their ideas about the course with each other and me so I scheduled both focus groups and individual interviews.

I held three focus groups with three-four students at a time and interviewed three students separately. Gwen could only schedule a phone interview. Once again, I paid students for their time and transcribed all tape recordings and/or notes.

The end-of-the-semester survey was handed out randomly to three hundred students before the final exam. Two hundred and thirty-six surveys were returned and analyzed on an Excel spreadsheet. Themes from the student interviews and initial data analysis from the survey was presented to Jim during our final interview/discussion in June.

<u>The Final Interview: *I survived.*</u>

> The biggest thing, the thing that I don't like about [the lecture setting] is the disconnect between me and [the students]. I was surprised that I even let myself fall into that – like I'm up here just lecturing and you're down there and we are going to be playing those roles for 50 minutes or an hour and 15 minutes and then we are going to go on our merry way. And I don't really get to know any of you unless you have problems or unless you see me...that big class formal thing is not – I don't know... I sort of played that role but not because I liked it or think that that's the way it should be.

It was the end of June before I met Jim for a final interview. Since the semester had ended he had been busy hosting an international conference, writing papers, grading, completing departmental responsibilities, and preparing for summer meetings. We met hours before he was to catch a plane to the first of two consecutive conferences. He told me that sometime in August he expected his schedule would slow down and he could “vacation”.

We touched on many issues during the hour-long discussion. My goal was for Jim to state his intentions for teaching the course again. What would change, what would be the same, what is still an issue, and what is possible? We discussed his ability (or inability) to schedule his time and say “no” to new projects. He explained how the department was going to restructure the Introduction to the Earth’s Oceans course by separating it into two courses and adding a professor. He talked about how the course would change and how our project impacted his teaching and thinking. I brought up the question of how this course could interest more women and minorities in science. I also verbally summarized initial findings from the final student interviews, focus groups, and end-of-the-semester surveys.

Below are Jim’s statements regarding how he will teach this course in the future. A new teaching environment, new resources, and a procedural change impacting where and how students are assessed outline the differences he envisions. His future hopes and intentions belay the tensions faced as he struggled to balance teaching this course with other job responsibilities, others’ expectations, and his own beliefs about effective learning environments. They also reveal optimism that his vision can be achieved.

> Next time around it will be a completely different course – completely. It will have its own identity…. It will evolve. That’s what I felt about this semester. I survived. I got through most of the material I wanted to… It’ll be much improved and will continue to change every time I do it.

A big impetus for his optimism is that he will teach the course in a different environment. For one, he will know how to teach a large lecture class. Next, he will teach half as many students. And the classroom will change. He explains:

> I’ll be a lot more comfortable with the setting. When I was reading on some of these sheets that the professor is unapproachable – that just blows me away.

> I'm only going to have to teach it once. There will be no more two lectures. I'm really glad that they are changing that because I don't think... I wouldn't do that again. It's not fair to the students, it's crippling to the productivity of the professor. It's just that you end up with a lower quality product.

> I'd teach it in a bigger classroom.

As the quote that started this section illustrates, the "disconnect" Jim felt with the students was very frustrating. In the different environment of the future he hopes for more connection with them:

> ... as far as ways to have more interaction – where with only an hour and 320 people [next time] – maybe it will be a little easier. When there are only 320 and not 640 – it'll be a little bit easier to focus on the same faces – I'll have half as many people.

Jim will redesign the course so it will "have its own identity", that is, one that focuses more on physical oceanography than it currently does. In that way, it will better match his research interests. Different and potentially new resources will foster that change. Another aspect, too, of Jim being "more comfortable with setting" also supports this change with respect to his use of the established course workbook. Jim describes the use of these resources below:

> I will use totally different material. I'm going to use a lot of video.

> I'm not going to use that workbook. And whatever exercises we do will be directly tied to whatever we talk about – directly... I think we should all have our own [curriculum]. [The other professors] don't want it to be [just one way] – well, I think they are very open. They have been teaching this class for 15 years... and they have developed the workbook and ... I think it's a very personal thing... I'm going to start developing my own thing and it is a little tricky. But they are totally open to it. ...I think I would take some of the ideas and topics out of the workbook that I did touch on and teach on and maybe focus less about punching in a few numbers on your calculator and instead thinking more about the big picture.

> I think I will [use the same textbook]. The diagrams are good... I wonder [though] if we should even be having a textbook. I think that there's talk to change that...

> I will use the web next time I think.

Although the methods for assessing students will not change, procedurally, Jim envisions a few differences. One difference may be to have graded work completed on-line instead of during class. The idea is to continue with in-class activities but to not grade them. Jim considers the impact of that change on student attendance:

And have homework assignments, or have them all online on the web. And there will be a significant drop off in attendance. But I think that a few people who have taught it are thinking that maybe that is not a terrible thing – with the behavior of a lot of the students who don't want to be there.

I'll do fewer exams. I think one fewer.

Student activity in class will not change. The overall lecture format will remain the same and students will work cooperatively on in-class activities and exams.

...the students will work in groups, for sure.

I think I'll stick with pyramid exam format.

Jim describes a sort of "tailoring" that will occur to give his course of the future a unique "identity". He believes that this effort or continuous improvement, coupled with the structural, procedural, and resource use changes will increase the quality of the course. How did the assisted action research project influence his thinking about the course and teaching in general? Following a reading of my descriptions and analysis of our project he commented, "This is really great stuff. It's really making me think about things. I think it's important work." During the final interview, I asked:

> Tarin: Were there ways that you thought about your teaching any differently this semester by virtue of the fact that I was showing up to your office and talking to you about these things?
>
> Jim: Absolutely. For sure. It was great. In fact it will have a lot of impact in how I teach it next time. It made me think more about what I was doing too – although I didn't have the time unfortunately to make a lot of the changes this semester but even two weeks into the class I was already thinking about the next time I was going teach the course... how it could look, what I might change.

Though my interaction promoted Jim to reflect on his teaching situation, he remains unsure how to think about and teach science in a way that motivates and is explicitly inclusive of women and people of color. Our discussions raised such issues but did not progress to a point of fruitful understanding. That, however, was intentional on both our parts. From Jim's perspective:

> Some of the things that always puzzled me were the gender and ethnic issues that we talked about initially in the beginning – but I, there were other things going on, I guess at this point my perspective is that I just try to treat everyone fairly and the same, and I don't know in science how to address some of those things...

Jim acknowledges that he didn't have time to focus on these issues - that he had "other things going on". Realizing that, I chose to support the more pragmatic issues confronting his teaching and embed characteristics of inclusive pedagogy into those discussions rather than allow them to guide our focus.

Another example of my efforts came during our final discussion. I reminded Jim that as many 1/5 of his students were unsure about their majors or the career they hoped to hold in the future. Related to that, the end-of-the-semester data showed that while 39% of the students agreed that they could relate what they learned in the course to their everyday lives only 14% felt that could apply what they learned to their future career. We agreed that the course should change to better connect to students' lives and futures. Jim said, "they should, you're right, this should be higher. There should be more connections that make sense to them."

I asked him, "How do these students learn about being a geologist? What makes them see that as a possible future or interest? Who will inform them of the important connections that exist between their career goals and learning about the ocean?" I shared with him how difficult it was for students in interviews to describe how the course was relevant to their lives. Many students thought the course was "interesting" and believed that in some far off future them may use the information they had learned.

We then talked about explicit ways a department could interest students in a science major. We brainstormed that a department could, for example, hold an open house or run a slide presentation in introductory courses showing the names, faces, and actions of those in the department. Perhaps flyers could be posted to interest students. Jim, agreeing to the importance of the issue, asked if I had shared my thinking on this topic with others in his department.

We ended Phase II of the project following this interview. I have little doubt that Jim will, over time, construct the Introduction to the Earth's Oceans course to better fit his hopes and intentions. He made strong efforts to incorporate elements of an inclusive pedagogy into his teaching and interaction with his students over the course of our project. We both learned, I believe, what is possible as we negotiated and sought to transcend the practical.

Mary's Project

Mary, Liza and I met for our Phase I meeting six weeks into the semester. We met after class around the large table that sits at the front of the classroom. I brought sandwiches. We relaxed, ate, and talked about families and deadlines. We laughed. We focused on the course. Our meeting lasted for ninety-five minutes. By that meeting, the Introductory Genetics course had met thirteen times and I had observed nine of the classes. I had interviewed both instructors and six students in the course. I had collected and reviewed course documents. At that meeting, I summarized data from the above sources and brought up questions about the course and teaching from a feminist perspective. Mary and Liza discussed course issues and set the focus for the starting point of the assisted action research project.

It is important to note that the Introductory Genetics course had been taught once before I began the project with Mary and Liza. A semester earlier, the Introductory Genetics team had brought the course to a local town's senior citizens through a learning in retirement program. About eighty seniors took the course and, based on evaluations, thoroughly enjoyed it. The course was strictly lecture with one laboratory activity, there were no outside readings, homeworks, quizzes, or exams. The seniors, according to Liza, were very interested and many answered and asked questions throughout each lecture. A big challenge to the team became revising the course to become a general education science course for undergraduates. That revision process was already underway as the spring semester began.

Phase I Data Summaries: Considering starting points

Instructor Summaries

Mary set our focus by first discussing what was going on in the course and what she felt needed attention. She asked a question that was central to her as a teacher and became a guide for subsequent thought and action during our project. She asked, "Am I up there doing too much of the talking?" She also wondered if there was too much material being presented and how they could get students more involved during class. Student attendance in the first month had been good and she was pleased, however, even though they came to class it was hard to know how students generally felt about the course. Some would ask her questions and have discussions with her after class but she wasn't sure how representative they were of the whole group. She said, "It is certainly easier to stand up there and talk to them and let them leave, there's no question about that. But to me that's not what this is all about." Her goal for how class time should be was more about sharing knowledge and participating in a dialogue about the science and how it impacted life with students.

Mary emphasized that designing this course was and would be a long process and reasoned that she (and Liza) would deal with issues as they arose. For example, at that time her main priority was "meshing in [ethical, moral, and political] issues with the original science content" so the students would understand the relevance of the subject. She hoped she would learn, over time, where other changes to the course were needed. One way she tried to gain this understanding was by asking students in almost every class if there were problems she could address.

Mary reflected on how it was to be teaching the course. Teaching a new course and developing it at the same time was an experience she had not had in a long time. Besides not knowing how these undergraduate students felt about the course, which was new to her because she felt she had a good sense for how graduate students viewed her courses, Introductory Genetics demanded a different level of organization than she was used to. The demands of preparing lectures and coordinating homework, reading assignment, quiz, and exam development within a team of busy people was a constant challenge for her. "It's a constant negotiation," she said. "I need Liza's perspective on all this constantly. We meet periodically to discuss issues."

Liza spoke next. "I really like what we're doing, it's terribly time consuming but exciting and we're learning so much!" She explained she was "spending time covering things, gathering materials for Mary to put on the web and use as OWL [homework] assignments because that's the practical side of what needs to be done to keep the course going in this direction." She was also reorganizing web pages to more accurately reflect what happened/was going to happen in lecture and writing/editting quiz and exam questions with the teaching assistants Ramya and Hans. She had questions about whether or not students were accessing the Powerpoint slides posted on the website and if the slides were helping them learn. Liza, however, hoped there could be time for her to do other things, such as investigate new content issues and develop more interactive learning modules for the computer. Her intention was to allow students to see and manipulate the models presented by Mary during lecture. Mary hoped that she could get ahead by just one lecture to give Liza time to explore other teaching strategies and assignments.

Here we see that early on in the project both Mary and Liza were considering questions that could be explored through our assisted action research project. Mary wanted to understand if she was "talking too much" during class and if too much content was being presented. Liza wondered about students use and the utility of the computer-aided aspects of the course. The data I had collected during Phase I illuminated some of Mary and Liza's issues and raised additional questions.

Tarin's Summaries

As I presented data to the instructors I was mindful that, though it was apparent they enjoyed the work involved in this course, they had also just described to me how overwhelmed and overtaxed they felt. Attempting to develop and teach a course at the same time was taking its toll on them. That realization led me to tone down some of my more critical issues and raise them benignly at the end of our discussion. This was a spur of the moment decision based on my sense that they had more immediate issues requiring attention. I presented my findings by first summarizing the student survey sheets and then highlighted issues and themes that emerged from individual student interviews and my classroom observations.

I began presenting data from the student questionnaires (See Table 15 in Appendix I) that had been completed by eighteen students (nine women and nine men) during the third class session. The questionnaires revealed demographics information about students as well as their interests and general expectations of the course. I summarize the salient findings in the following paragraphs.

Student status in the course varied with six freshmen, four sophomores, two juniors, four seniors, and two graduate students taking the course. Students' academic interests also varied with students declaring majors in math, education, microbiology, biochemistry, computer science, psychology, sociology, English, history, and fine arts. One freshman male was undeclared. For the Phase I meeting, I briefly reported on students' generally high expectations about course relevancy. In general, the majority of students agreed that what they would learn in this course could be applied to their everyday lives and that everyone should learn about DNA (fourteen and fifteen, respectively). Four students were not sure if the information could be applied to daily life and one student disagreed. Three students were not sure if everyone should learn about DNA. Eleven of the eighteen students agreed that what they learned in the course could be applied to their future career while six students weren't sure and two disagreed. This data seemed to correspond with how both Mary and Liza expected students would be thinking about the course. The instructors created the course believing that students would want to know more about their DNA and how it impacts their lives now and in the future. Plus, they had also already had students complete an information sheet on the first day of class and were knowledgeable about student majors and years.

Through the questionnaires, nine students (six women and three men) volunteered to participate in the project (See Table 16 in Appendix I). Of those students, there were four freshmen, one sophomore, two juniors, and two seniors. One student, Winston, was Korean and the rest Caucasian. The students' majors were business, microbiology (two), psychology (two), sociology, computer science, English, and history. Students interests varied; violin, pop-psychology, singing, and philosophy, to name a few.

I then highlighted the themes issued thus far from my classroom observation notes. Similar to Jim's class, I took observation notes that emphasized teacher-student/student-student interactions, activity in the classroom, and my personal questions and suggestions on instructional methods or content. I wanted to offer Mary and Liza a summary of those.classroom elements that were significant to a discussion about course design and change from a feminist perspective. I summarized three such elements of the classroom. First, I illustrated the ways that they had worked to make the classroom welcoming, comfortable, and supportive of student learning. For example, in all of the presentations, I observed either Mary or Liza smiling and greeting students as they entered the class and in four classes Mary expressed appreciation that students chose to take the course. In addition, during all but one presentation, students were implored to ask questions about anything that was confusing about the content or how the class was being run. Mary often made statements such as, “Are there any questions? It’s all crystal clear? Please stop me if you have to - I won’t know otherwise!” (Observation notes, 2/5). Also, because I observed students smiling and laughing when Mary told content-related anecdotal stories (such as blowing up a gel while conducting a sequencing lab or the antics of her twin nephews) or brief histories of scientists (i.e. Rosalind Franklin and Paul Ventner) it appeared that a comfortableness was being created in the classroom. This was further enhanced by both Mary’s and Liza’s continual plea that students do not get bogged down in the language of DNA and their insistence that it can be understood. Mary, for example, said to students during the fourth class, “The limits to understanding this is the vocabulary, I want you to understand why it’s so confusing to people – it’s because we’re not using the same language – but it is understandable!” Liza explained to a student during the third class how his question was confusing because they just “needed some common language” to work together from. She then worked to create such language while teaching. Using these examples during our Phase I meeting allowed me to highlight the ways that the instructors were working to give students voice, connect science to real people and events, include sociohistorical aspects of scientific knowledge creation and change, and teach using everyday language. Mary was pleased that the classroom seemed “comfortable” for the nonmajors who may be “scared” of the science.

On the subject, though, of making student “comfortable”, I noted that only five or six students actually asked or answered questions during class. It was doubtful that they were only ones with questions or answers, especially since they were all juniors, seniors, or graduate students. Of that group, females and males talked approximately the same amount. Now and then, when underclassmen did speak up, they asked questions that were tangential or unrelated to the content. Instead, these students asked about friends with diseases or if a topic was similar to something else or logistical questions about exams and homeworks. I pointed out that, inour first interview, Mary had explained how she expected students to be quiet in the beginning of the semester but hoped that, overtime, they would speak up more;

Mary: Well, in the beginning it seems to be that they are going to go from being in their own little – right now they are uncomfortable with the topic, with the idea, they are uncomfortable with this whole thing. And the first shift is that they become more comfortable asking questions and talking about things...where previously the vocabulary didn't exist.

Tarin: So are you hoping to see them asking more questions in... two weeks? You are hoping to see a progression like this?

Mary: But I'm not sure...

It seemed that by now, seven weeks into the semester, Mary had expected more students to be asking or answering questions in class.

Another theme that I raised was that course structure involved repetitive structures that existed in how the course was taught. Mary began her Powerpoint presentations with a review of information from previous classes. She would often show new diagrams or use new slides to review information. For example, a discussion of RNA (ribonucleic acid) that began on 2/14 was still being reviewed on 3/7. There was also a repetition in her Powerpoint presentation in that there was usually always an introduction, content-emphasis, application of knowledge, and implication focus. In this way, effort was being made to give students a rhythm, a structured way to think about the old and new material. Another repetitive structure was the use of the course web-page as a source of information, assignment listings, and OWL homeworks. In time, students learned the routines of checking the web page for readings and assignments and how to complete the on-line homeworks. I commented that, based on the comments of non-science majors I had interviewed, such structure was crucial in supporting students' efforts to learn the content. It also had the possible downside of making the course seem too routine.

Finally, I noted the ways that the instructors' enthusiasm and personal commitment to learning about the subject motivated students to learn and exposed them to the relevancy and tentativeness of the science. Mary and Liza constantly demonstrated through their words and attitudes of enthusiasm and wonder that even experts like themselves continued learning. In one class, Mary told her students, "As a teacher, I know how much I don't know when I have to teach it – it's important to say there are things you don't know about – any questions?" In addition, accompanying her colorful Powerpoint presentations were cartoons to highlight contentious issues surrounding a topic, or moving animals to emphasize or, at times, ridicule a point. Accompanying her visuals were her expressions of wonder, "Wow – this is just so neat!" (2/7 observation notes), "I will always be amazed by this- we sure don't understand it yet!" (2/12 observation), and "You have to be cautious when reading some of these [popular press] articles and come at them with a healthy skepticism about these [biotechnology] companies. I'm interested in checking up on this company to see if the article has any weight" (2/5 observation notes). On this topic, during our meeting, Mary made this comment:

> Well, I don't know everything. I learn stuff all the time. Liza finds stuff and sends it to me and I read it and add it to the lectures. It is changing, so fast... there is so much to tell them, I just hope we figure out the right mix.(Phase I meeting)

Following summary themes from my observation notes, I read or paraphrased quotes from students that related to and/or supported my themes and raised additional issues. For example, students overwhelmingly commented on the instructors' ability to make the classroom welcoming, comfortable, and supportive. Only one student, Tom, alluded to my theme of repetition. Three students made statements relating to the instructor's love of learning and enthusiasm. Three students talked about how they were learning new information. Below are the related quotes;

> It is not even how I expected. I was expecting to be in a science building and like – I don't know – I expected more emphasis on the just the text. It's more informal - but in a good way... I think they are really – seems like they have our learning – like in mind – the entire time. They want us to learn it and they want us to understand it and not be intimidated. And I can tell – like if I have asked questions they have provide a very comfortable environment for questions – where as there are some classes where you are intimidated and afraid to ask because you think that the teacher is going to ridicule you or make you feel like you should know this...so they are very good with that. And the way they explain things and how they are interrelating the scientific with the issues. (Amanda, talking about support)

> The ambiance, like I said, the enthusiasm too is a good thing... And [talking], she encourages it – because the first day that I went in there I remember thinking that it was nice because she always stopped and said, "Are there questions, please?". It was very much like that because I think she knows a lot of the stuff for people, like me especially... as I look around the class need clarifying. It was the first time that I have heard this information. (Heidi, talking about a good ambience)

> I think we have two very highly motivated, very energetic professors who really want to see us learn about our DNA and genetics and DNA technology and a lot of the applied fields. And I really like that ... I am a graduating senior and I am taking the class because I need credits and the subject is interesting and actually to arrive in class and

have two professors who are just as excited to be there as I am. I think that is wonderful! (Tom, talking about enthusiasm)

And I really like having assignments posted on the internet – and you check the internet for the assignment – it is good because they just don't tell OK for next week read this - and so you have to kind of keep checking with the web page and so it kind of demands that you be organized and keep a schedule and stay on top of all the readings... and I think that is good particularly for ... lower under classmen who come here from high school – where it is very rigidly structured and then you come here and you are supposed to be responsible – yet no one is holding your hand and so I like that. (Tom, talking about course structure)

Their lead introduction - it seems like, "Gosh, we don't have any idea about DNA!" – critical stuff and so I decided to take this course and it is a very interesting course. They like it and get us to think about it and learn it. (Winston, talking about learning)

I am a big fan of NPR and I remember I think it must have been last summer or sometime I can't remember exactly when it was - but I was listening to it very, very, very heavily ... and I remember listening to it and then feeling like I was getting lost – like I didn't exactly know what they were talking about ... and then they would say something else and what does that mean – and nobody I knew could really explain it to me... It was all very exciting and I like the fact – that is why I like this class so much - you are learning the nitty gritty stuff but you are also learning how relevant it is to life and to everyday topic issues. (Heidi, talking about relevancy)

I would like to also be able to listen to these things and actually know what they are talking about. And feel like I am actually... an educated person and I am knowing it - and now- well, somewhat, I can talk about the things ... I mean I can talk to people and know what I am talking about. (Caroline, talking about learning)

In our interviews, students also talked a lot about the Powerpoint presentations, computer usage, and areas of confusion. In general, students appreciated the use of Powerpoint during lecture. They liked the images and diagrams detailing the text and Mary's lectures about cells and DNA structure. A few felt lost at times during lecture. Jake and Lydia sum up these ideas in the following quotes:

The Powerpoint is fantastic. It really helps to see the images and follow along with her words. I'm a biology major and had never seen these images before – it really helps make sense of things. (Jake)

She goes into way too much detail and talks and talks. I can't really follow it all. I like her though, she's into it and that's good. She gets us interested but I just can't follow it all. (Lydia)

Lydia's quote echoed Mary's original questions about whether she was "talking too much" and how to get the students more active. Again, Mary pondered how this could change in the midst of just trying to set up the Powerpoint, "... it's under development, this is a process, I hope things will be put in place," she said.

Not all of my interviewees had logged on to the course website at the time of our interview. Of the seven who had, early reactions were mixed. All but one student liked accessing assignment schedules and readings on-line. Amanda said it was useful because

> when you miss certain things and you can go back and refresh your memory and receive visual aids" and "it kind of gives you a feeling - like instead of them just handing something to you and you have to read it ... it seemed more like something I was doing for myself like just browsing the internet.

Lydia liked that she could "check what's going on [because] it's good to know the information is there" and Jake commented, "It makes total sense to use it – it's great." The OWL homework assignments were frustrating for four of the students. Those students felt the OWL questions, with multiple multiple-choice answers were too tricky and that answering often became trial and error guessing. Winston, a computer science major explained that,

> I have used [OWLs] now for years so sometimes you get really stuck on it - not because you don't know anything but because the systems are not as good as... well, it is like this – the computer system is a little different than the human brain and it is not as smart as human – so it doesn't really exactly interpret your answers to the correct piece.

Lydia said

> The OWLs are hard sometimes, it becomes too hard to get all the right answers and I just end up trying everything. It should be more straightforward and not so tricky. More like a review I guess... I just do them ... do I see a direct connection? No. Again, it's too much detail. I think the idea of them works – I like the feedback she gives us – I don't know.

OWL homeworks not withstanding, Heidi found computer usage for this course difficult in many ways.

> Honestly - I try to get away with the bare minimum because I don't like being on it – I don't like the internet – I know it is dumb and silly of me – but I just – I don't feel comfortable with it and I don't have any access in my own apartment – which is a big thing for me because if it was in my apartment, I would probably end up playing with it. And going in on it and now I have to find time within my day between classes and work - you know go find a lab and sit down – and by using it – just printing this out and then going home and reading it.... And actually I found that a lot of my professors somewhat discouraged doing research on the internet in history –because there is a lot of stuff out there that is not secure and so it is not the preferred way to do it... I really hope that this is not going to be that much of a problem for me. Mary said I shouldn't be worried because she is working all day and there are tons of computers on campus and if I needed to she could set me up with one in her office. She is very... good about it.

Liza was very interested in student thinking about the OWL assignments. She explained how OWL itself had a difficult structure making it hard to use and very time consuming to set up. She felt that because student could retake the OWL quizzes they should not have to worry about their grades and instead be able to focus on learning. She worried, though, if their frustration was keeping them from trying again. She planned to simplify the OWLs and continue urging students to email her their complaints and suggestions. She thought that her feedback written into the OWL assignments was helpful and was glad students seemed to agree. She stated, "It's hard to know what [the students] think."

There were, of course, other issues that students raised during our interviews and I shared them with the instructors. Again, I grouped student comments. Four students talked about aspects of the course that were confusing. For example, Lydia, at this early point in the semester, seemed unsure if the course would benefit her future, "I want to go into forensics and work for the FBI – study criminology and the criminal mind. I don't know if this course will really help me or not." Janet expressed confusion about note taking and wondered whose responsibility it was make sure lectures were understood. She said, "Sometimes I don't know whether we should take notes because… I don't know how to explain … there are some things that I am not sure if I should write down," and added, "I don't think it is only the professor though – it is the students also that we don't feel like we can [ask questions] and maybe we just have to get over that and just go up and talk." Annette felt, at times, that the lectures had "become extremely boring and repetitive". She explained that, "after reading and understanding the materials the night before, I was essentially learning the same thing for a third time in lecture." Though she felt the repetition was important, she wondered if there was a way for her to be challenged more during class. Finally, Caroline did not understand the co-instructor situation, saying simply, "You know Liza? I don't know why she teaches. Mary is the teacher and she should be the one teaching. It's confusing with two."

I also grouped student comments about the quizzes. Five of the students remarked that they felt the quizzes were tricky and/or difficult. Winston's and Caroline's quotes are good examples of this:

> So far the second quiz [was] especially sketchy…the structure itself – it was confusing… My feeling is that it is hard to know what [the question] means – hard to know what they will ask, in what way. (Winston)

> Sometime they are a little tricky. I don't like how one question may have two answers. I don't like that. (Caroline)

The other students felt the quizzes were, "okay", "fine", and "made you think". Annette said, "They're fine. I really have to focus and don't get them all but they're fine."

On this issue, Liza explained that she edited the quiz questions that Ramya and Hans, the teaching assistants, were writing. And, though, the editing consumed much of Liza's time, both she and Mary felt that they needed practice writing the questions. Liza agreed that some of the quiz questions were confusing and said that they would improve. She hoped I could continue to get feedback from students about the quizzes.

Finally, I raised issues on two topics that I felt needed discussion; student participation and awareness of the "science-as-usual" quality of the course. I tried to relate the issues to the instructors' intentions for the course. At the start of our meeting, Mary wondered about student participation. She hoped more students would formulate questions during lecture and that they could somehow be "more active" during class. She explained her goal for these students' learning

> … in that little bit of information they'll be able to understand a lot more about what they hear in the world around them and they'll begin to pay more attention to, for instance, if there's a debate on an issue or a topic that's important to them.

My issue for her was, "When do students get to apply their learning? When are they given practice using what they have learned so that it becomes useable knowledge that can be applied to a 'debate on an issue or topic that is important to them'?" I explained how students did a lot of their thinking about this course alone, while studying or taking OWL quizzes. I suggested that, for students to become literate in the way Mary hoped, they needed opportunities to muse together, in class and with her guidance, on everyday problems about DNA. The structure of the course was set-up in such a way that the students' assumed the passive role. To get them to talk more, participate more, and be more active during class required a change to how information was communicated to the students. I suggested incorporating more formative assessment strategies. Mary agreed that, though she was unsure how to make those all those changes, they were important. She explained how, for starters, the individual student projects would offer students a way to be more active, to work in groups, and to focus on a personal interest.

I also raised "Whose science? Whose knowledge?"-type issues (Harding, 1991) by reading off a list of questions that focused on the purposes of the content being presented. I asked;

1) Why are white men the most publicized and taught about scientists in this field? Who today is female or of color doing this work (besides yourselves)? Why aren't they famous?

2) What is ultimately driving this research? To what end? Is it for medical advancements and pharmaceutical gain? Pure knowledge acquisition? Global philanthropy to improve the plight of all people?

3) How much does it cost to reap the benefits of this knowledge? What nations can afford to use this knowledge and what nations cannot? Are there other places money for research should be spent to benefit more people? For example, immunizations? Medicine for diseases? Family planning? Is it an issue of the flow of money and its political components? Essentially, who is asking the questions and who benefits from the answers?

4) How do you open up this enterprise to the students who may be undeclared or become more interested in studying DNA? Should an introductory course not only serve to "inform" students but to invite them and include them into the major? Who or what influences these students? Can these students become scientists too?

With these questions, I tried to further infuse a feminist perspective into our discussion of course design. Mary agreed the questions were compelling, however, she wasn't sure how these issues fit into an introductory level course. She was focused on teaching the science and including related ethical and moral issues –an emphasis like this would likely be lost on these students who don't even understand the science. Liza felt this issue of "Whose science? Whose knowledge?" had a place in the course but that fitting it in would be extremely difficult in the midst of all they were trying to do right now. In the future, however, they would like students think about the information and why it exists and how it is being used.

On the question of who can "do" this science - Mary and Liza explicitly stated that they were not trying to make these students into scientists. Mary had even stated that to students during class. She, however, did not rule out that some students may become interested and pursue a degree in her field. She was, though, unsure of her place in that decision. Again, explaining that the aim of this course was for general knowledge acquisition on the topic of DNA she wondered where would scouting for majors fit in? Would students even listen?

<u>Phase II: Choosing a Starting Point</u>

As our meeting time was quickly coming to an end I summarized my notes for the instructors, focusing on their questions and issues. Mary was interested in learning more about students' thinking about lecture, essentially, her "Am I doing too much talking up there?" question. She wanted to know how students "felt" about the course and how they could be more active during class. Mary would continue to solicit student questions during class.

Liza wanted to continue learning about computer usage by students; "How was OWL going?" and "Are students accessing Powerpoint slides on-line?" She planned on simplifying the OWL homeworks and would work with Ramya and Hans to create more clearly worded quiz questions. She would continue asking students to email her comments about OWL.

We agreed that I would continue observing classes focusing on dialogue, interaction, and my questions. I would also email students general questions about the course using the 1 + 1 response protocol (described in Jim's section). I would email information and questions to Mary and Liza up and we would meet again in April to discuss our progress.

<u>Phase II: Action Plan and Outcomes</u>

We began this phase of the project with the hope of gaining more understanding of students' thinking about lecture, how to involve them more in class, and their impressions of computer usage (OWL, accessing information on-line) and the quizzes. We also wanted students' general impressions and suggestions for course change. This effort began as, day to day, Mary struggled to keep up with lecture preparation as Liza worked to integrate OWL homeworks and quizzes with the daily lecture topics. They met ad hoc to plan and discuss the course with the rest of the genetics team.

Not long after our meeting, Mary made an explicit attempt during one lecture to bring out the students' voices. In a typical class, Mary asked content questions with no real pattern. In fact, of the sixteen classes I observed, the number of content questions asked ranged from one to eleven. During a lecture in late March, however, Mary engaged the students in a five minute question-answering scenario guided by her Powerpoint slide. My classroom observation notes effectively capture this scene;

> Next slide up says, Questions for MyDNA. The slide has five questions on it related to the steps of cloning an organism. [I have never seen her put up a slide like this before! It is very clear and, I believe, allowing us all to get on the same page with respect to what is being asked and giving us time to think about the questions.]
>
> Mary: (reading off of the slide) What do you need to start cloning? [Let's say], to clone a spider silk gene?
>
> Male student: Sequencing.
>
> [Mary]: What else do you need?
>
> Students: (no responses)
>
> Mary: Do you need somewhere to put them?
>
> Tom: (explains about cutting up spider gene, etc.)
>
> Mary: Exactly – you want to cut them up. [You need] spider DNA, vector DNA, paste them together, need restriction enzymes, ligase - and lots of money to do this too...
>
> Jake: If you have the right control sequence then... [missed words].
>
> Mary: Right. If you have these special control genes.
>
> [Notes: Didn't catch it all. This is a unique situation, a kind of guided lecture to promote ideas and questions – most students didn't respond, they waited, the usual males spoke. It is, though, a good start to getting students to think and participate – maybe coupled with some writing time it would prove more fruitful?]

Using a Powerpoint slide in that way was not repeated again in any more of the lectures I observed. Instead though, Mary and Liza began using the slides to introduce the student project idea to the class. This brought out more discussion as students inquired about the logistics of the project. It was explained that the project idea could offer students opportunities to share in class and interact with more each other and the instructors. The projects would allow students to focus on their interests and would help to reveal those interests to the instructors.

Mary and Liza asked me questions about assessing students' projects and presentations. We talked about rubrics and, because neither instructor had used one before, I forwarded them related websites and examples of rubrics from courses I had attended. After some back and forth editing, they developed a rubric that detailed the student project specifications and assessment goals. Once the students had reviewed the rubric, the instructors asked students to write short explanations of their topic interest. This effort touched off a cycle of communication between Mary and Liza and the students. It allowed the instructors to suggest possible collaborations. It also forced students to begin the project.

Mary and Liza took on an added workload with the addition of the student projects. They divided the class in half and each was responsible to correspond with students through email about project ideas, questions, and progress. Mary carbon copied me on the emails she sent to students. Of her group of nine students, she sent out approximately five to seven emails per student or group (she only had one group). Liza undoubtedly took on a similar workload. Through these interactions, the instructors worked hard to keep students on track and opened a dialogue with them about their project topic. Mary wrote students long supportive messages about their topic of interest that often included web searches. Below is an example of a few correspondences between Mary and a student, "Lucy". Though lengthy, I include it here to illustrate the time and energy she put into this component of the course. I want to remind the reader that she had similarly lengthy correspondences with other students.

> Hi Lucy: We think a court transcript about a case where DNA was crucial evidence would be very interesting and we want to help you to develop and clarify your ideas. Please be sure to respond to these specific points in your revised Project Proposal due Tuesday, April 2.
>
> 1) Your idea of using actual court transcripts from a real case(s)that depended on the DNA evidence is great!! Many people have been proven innocent using DNA evidence, some who were on death row. Makes you stop and think. Anyway, NOVA has a great on-line site about DNA evidence and I pasted a fraction of that information below to give you an idea of what they have. Also, please go online and find the "Innocence Project" at the Cardozo (sp?) law school for tons of information on this amazing impact of DNA technology. Ironic to think that the lawyers who started the Innocence Project were the same lawyers who defended OJ Simpson on his "Dream Team". If you find specific

cases of interest to you, I will ask my lawyer sister how regular people go about getting access to court transcripts (unless you already know?). Meanwhile, you should do a search online for 'court transcripts' to see the format they generally take, and then repeat the search adding keywords like DNA, or genes, etc. to try to see what is already out there. This might give you some additional ideas about what the case could be about," DNA has played a central role in many paternity and estate cases etc. 2) If you decide not to focus on court transcripts for whatever reason, perhaps you could design a case study to be used to provoke discussion in a high school level class. You would not actually interact with a whole class (although we might be able to "dig up" one high school student). If this idea appeals to you look at examples at http://ublib.buffalo.edu/libraries/projects/cases. Especially see the one on breast cancer as an outline to see how deep the instructor goes into the science etc. >Please submit a proposal that follows the guidelines so we can best help you focus on a DNA topic and help you to find the information you need. Send it by email to Mary

>Thanks, Mary and Liza! For the DNA project I was thinking about putting together a book on trials involving DNA evidence. I would take a collection of court transcripts and put them in the book, some would be of people found guilty because of the evidence, some who were innocent, some who got off death row because of the DNA evidence and some who died on death row who were later exonerated due to the evidence. For each transcript/case I focus on I will provide background information on the case and explain the circumstances of the DNA evidence. I will include ways in which the DNA is found, how they analyze it, etc. I am not sure how to go about getting transcripts from actual cases, I am not sure if they are published online? Thanks, Lucy

Lucy: Your idea of compiling a "book" about trials involving DNA forensics is great and we hope that you have made progress further developing your idea since we are getting close to the end of the semester. We are sure people would be interested in hearing about what it is really like in court. Unfortunately it took awhile for me to get further info from my sister the lawyer. She said "Court transcripts are public documents and therefore available from any Clerk of Court. Sometimes judges "seal" court records (proceeding is sealed and cannot be accessed without a court order). Otherwise, transcripts are available for a fee. Not every trial results in a transcript, however. All are recorded by court stenographers, but they are transcribed only if so requested and paid for by one of the parties. Transcription is required for appellate review, though. It seems your student's greatest difficulty may be in choosing a case to request a copy of a transcript from the Clerk. The best way may be to work backwards from a published appellate opinion, A law librarian could show the student how these opinions are accessible by subject and jurisdiction. The trial court number will appear in the appellate opinion, so the student will know which case with which number to ask the Clerk for." We think that it is probably too late to try to incorporate trial transcripts in your "book" considering the difficulty of accessing transcripts. Of course there is a huge amount of information about groups such as the Innocence Project at Cordozo Law School who have used DNA evidence to free so many people convicted of crimes, some on death row...

Please note that all FINAL Project Papers (from students who are NOT giving presentations in class) are DUE TUES. MAY 7!

The length, content and format will be decided by the student BUT REMEMBER TO REFER TO THE RUBRIC TO MAKE SURE YOU HAVE COVERED ALL OF THE NECESSARY POINTS!

Please let us know if we can help. Mary and Liza

As the semester continued I was amazed at the amount of writing accompanying Mary's responses to her project group's progress. It seemed to me that the amount of work she was doing definitely exceeded the time available as she continued on with her other work-related responsibilities and research. I oftentimes found myself wondering how I could help more.

Soon after the Phase I meeting, I too began an email correspondence with students in my interview group to begin collecting data on the questions that arose at the Phase I meeting. I asked my student participants to describe to me; 1) their impression of OWL homeworks and how it was affecting their learning experience, 2) what was helping them learn and what was impeding their learning, and 3) any other thoughts about the course. Six students responded to my inquiries. After reviewing student comments, I grouped responses by question, removed student names, and forwarded the results to Mary and Liza at the end of March. This data is summed up later in the chapter.

Soon after that, Mary and I met for a forty-five minute Phase II discussion up-date about the course and data collection. We did not, though, specifically consider the student data I had emailed her about OWL and the course. Other issues seemed, at the time, to take precedence. I had some questions about the content being taught and, falling into a student role, asked for clarification on a few topics. Most of our discussion was an up-date on the various parts of the course she was focusing on at this time. This meeting allowed me to see how she was acting on the data we had collected during Phase I.

First, in order to keep students' thoughts and ideas in the mix of what she was teaching, Mary had surveyed them (when I had been away at a conference). She wanted to be sure she covered topics of interest to students in the last third of the course. Since so few students expressed their thoughts in class, she said this was a useful way to get at everyone's ideas. She felt that early on the "quieter" students wanted to know more about social issues related to DNA but because they didn't have the science background they weren't really ready to explore answers or even formulate good questions. "Now", she said, "they should have the content to make sense of the issues." She also wanted to know if the students felt that their peers should have some background on specific topics prior to the project presentations. For example, a few students were reporting to the class about investigations that used DNA identification to find criminals. As a result of this survey, Mary moved up her lecture on PCR (polymerase chain reaction), a DNA reproduction technique, by a few weeks to give students background on how this laboratory procedure aids in the identification of an individual's DNA. She also hoped to infuse more socially related questions into the course as the students presented their questions.

Secondly, Mary was putting a lot of time thinking about her team and giving them voice to make and carry-out suggestions for the course. She interacted with Ramya, Hans, Paula, Jane, Chang, and Liza, to varying degrees each a few times each week. For example, Ramya had suggested taking the students on a field trip to the DNA sequencing laboratory on campus and she was helping with that coordination. She found some more money in a small teaching grant to pay Paula to help Liza and was checking on that situation. Paula would be able to assist Liza in OWL creation and set up "to make things run smoother... because I just haven't had the time to help out as I should on that area." This would allow also Liza to spend more time creating visuals and learning modules on the computer. And, because Liza's funding was running out and Mary was constantly searching for funds to keep her on the payroll.

Third, Mary was still preparing lectures for class a day ahead of time. Although her preparation was somewhat rushed, coupled with the assignments and readings, she believed students were getting "the take home message" of each lecture. She wished she had more time to prepare and create her lessons and reiterated again how the course was an evolution and there would be "lots" to change next time it was taught. The main questions she had at the end of this meeting were about student impressions of a lab they had conducted and the second exam.

Following that meeting with Mary, I sent around another email to students' about the lab they and the second exam. Because the course only had one lab I was very interested in what students thought about it. Six students responded to my email. Conducting the lab was a positive experience for all of them. Several mentioned that they had hoped the course would have more activities like this. A few science majors thought it was good but didn't really "learn" anything new. The students' responses about the exam were more mixed; two thought it was incredibly hard with difficult wording and misleading answers and the rest thought it was "fine" and/or "challenging".

In the next class, Mary, having heard that many students found the exam difficult, allowed them eight minutes to talk about the exam. This was the first time she had devoted a chunk of class time for discussion about how students' were being assessed. Below are my observation notes from that interaction. The notes illustrate another way that Mary and Liza attempted to increase students participation and show their continuing interest in students' ideas and impressions about the course.

> 4/11 Start of class – Mary asks, "How many thought the exam was too hard?" Many students (9?) responded saying it was "too picky", "questions were really specific", "there was awkward wording", "I got psyched out by the wording", "it required knowledge from different fields" and that "the review session helped." [No students who thought it was okay spoke up.]
>
> Following the discussion about the exam, Liza asked students about OWL.
>
> Liza said "there's a drop off in the number of people doing OWLs, for the last 2, only half the class did them – you get credit for just attempting OWL, for thinking about the issues… [how is it going?"] Tom replied that "the feedback on OWL is very useful" and Liza said, "That's good to know that you are paying attention to the feedback." Amanda added, "Yeah, the feedback is good, say why it's a wrong idea though, give us more about that." No more students' spoke up – why? I know some are so frustrated with OWL, why can't they tell Liza? Mary closed the discussion by saying, "You can email us if there is something – anything - you can think of that would have helped you to the learn for the exam better – feel free to write questions too for the exam or OWL."
>
> [Liza] added, "Just to let you know, the next OWL will take some time, there's information to read and you may want to space out the work – it's due in one week.
>
> Mary said, "Anything else about OWL or the exam?" [No more student comments, lecture began.]

The talk of frustrated students concerning the wording of the exams (and some of the quizzes) caused Liza to make an interesting change. As noted earlier, she coordinated the writing of the quizzes and exams with the teaching assistants, Ramya and Hans. She and I had been discussing informally the notion of formative assessments to allow students opportunities to reflect on their understanding of the content. For the next quiz, she handed out a list of vocabulary words and asked students to put the words into an explanatory paragraph. In general, according to Liza, the students "bombed" the quiz. Heidi and Lydia told me informally that it was "impossible" and "really hard". In fact, since so many students had poor grades on that quiz, the instructors offered a time to retake it. So few students expressed interest in even trying it again that, in the end, the instructors simply dropped the grades. However, the reality that the students could not write a paragraph of this type was not lost on the instructors. Liza commented

> If they can't do this – I mean what does that mean? Some did okay but most couldn't make sense of this. We definitely have to give them more chances to do this in class somehow, to get them to use the language themselves! (notes, informal discussion, 4/25)

At the end of April, Mary, Liza and I met for lunch to review the outcomes of our Phase II data collection. I also wanted to learn more specifically about the Collaborative's Fellows group that Mary was involved in. In my efforts to explicitly encourage discussion about how their work from a feminist perspective, I also presented and explained Dr. Kathleen Davis' model of Legitimate Participation in a Community of Practice (Davis, 2001).

Though Mary and Liza listened intently to my description of Davis' model, it did not motivate discussion. I restated that one of my purposes in the project was to investigate ways that teachers could better connect students with science by exploring their roles as door openers and gate keepers. The "better connection with science" position resounded with their hopes and intentions while the more political issues of social justice and exclusion simply did not come up. Mary furthered our discussion with a combination of ideas emerging from her experiences instructing the course, my work with her, and the Collaborative meetings. She talked about using pyramid exams in the future as one way to have students interact more and incorporate group work. She hoped to bring in more "hands on stuff" early in the semester and have students focus on social issues related to the content. Liza agreed. She hoped to involve the teaching assistants more in the class by having them work with small groups during activities and lead discussions. They both hoped the use of class talk could integrated into the course.

Mary then described her impressions of the Collaborative Fellows meetings. In general, though she was gaining ideas and meeting interesting people, it was difficult to transfer the ideas and goals of the meetings to her everyday practice. She commented that, "I'm just not sure what I'm supposed to be doing with all of this information." She worried that the theories of teaching and learning were taking up too much meeting time and wondered when she would have time to figure out how to apply them. Again, she explained how, if it wasn't for Liza, much of the Collaborative information would be lost on her.

> [Liza] keeps bugging me to read this or think about this... so if she tells me to learn it, and I hear it at [the Collaborative], and you talk about it, well maybe I can make sense of it and apply it... It is, after all, a collaboration.

The Project's Final Weeks

Besides listening to a guest speaker (a biochemist explaining his work on the evolution of complex organic molecules), the final three weeks of class were mostly student led. The students who chose to present projects (versus writing a longer paper) were given 20-30 minutes to teach the class. Students and instructors evaluated the presentations as they were delivered using a modified project rubric.

The projects and subsequent presentations were, in general, a positive experience for the instructors and students alike. Mary was pleased with the work the students were presenting, emailing me that one student did "a great job", and another's work was "awesome" and made her "rethink a few things". The students, as indicated in our final interviews, also spoke positively about the presentations. They found the topics timely, interesting, and engaging. Jake said, "[with the presentations] we went right into something that, you know, is on everybody's mind, something that's in the news, something that, you know, everybody had input". Caroline commented that, "I thought they were a great idea. It got me involved more." Tom added, "I thought it was real neat to find something that interested you and it was a good way to bring in material." And Lydia explained that,

> I liked having everyone pick their own topic because, like, I'm a sociology major and I'm interested in criminal justice and DNA forensics and since they didn't talk about that a whole lot I got to talk about it myself – and research it on my own and then do a little bit with that.

I began formally interviewing these students during the last three weeks of the semester. One student, Janet, could not schedule an interview. I conducted two focus groups with three students each and two individual interviews. Again, the interviews were forty-five minutes in length and students were paid for their time. I started each interview or focus group with the open-ended question, "How is the course going?" and let the students direct the conversation from there. Their statements lead us to discuss issues of workload, interest, learning, exams, OWL assignments, talking in class, and suggestions for more student interaction (small group work and "activities" came up often). I summed up my initial findings from the interviews and all the email responses from students for Mary and Liza after Mary made two requests of me.

In the beginning of May, she wrote;

> [Liza] and I would LOVE your help developing a really good way to get feedback and evaluations from the students to help us make the course better for next spring. Assessment, that's the word! I tend to get so busy that I don't think enough about the best way to get feedback (good and bad) from the students, and also the best way to tally those results so that they will be most useful to us. Can you help? Mary

In a subsequent email she added;

> Thanks so much, this information will be so incredibly important to us!!! Thank you! ... I must admit this is really the first time in 20 years that I have found teaching to be a challenge at all. Thank God for Liza. She has been such a great help with the course in every way, but she really cares about teaching quality and she literally makes me pay attention to rubrics and learning objectives and in class activities etc etc etc. AND she made it so much easier to take risks with all of this!! Now a complication... I am supposed to write a course redesign proposal. I look at it as an "opportunity" to think about how to improve the course, but usually I won't seriously get to this until the course is over and I have feedback from students. Is there any way you can give me what you think are the major points the students would like to see happen with the course? I would far prefer to hear what they say before I redesign the course!!! Mary

I agreed to do both. First, with respect to student evaluation of the course, I emailed my suggestion that they ask students to

> write out anonymously on paper things that have worked well in the course and things that could change. I would also ask [students] to consider that this class will grow in numbers over time and what do the instructors need to consider with a larger audience... I would also try to state for them the range of topics they can comment on such as lectures, in-class activities, OWLs, exams, textbook, other students, instructors, labs, field trips, movies, TAs, classroom, class length, content topics, projects, etc. It seems that when they see all those components it gets them going right away.

Mary and Liza subsequently created a evaluation and review form for students that asked them; 1) Which part(s) of the course were most interesting to you?, 2) Which part(s) of the course were least interesting to you?, and 3) How would you change the course to make it more approachable for non-science majors and more relevant to your life? Then students were asked to rate ten course components (i.e., lecture presentations, lab, guest speaker). Students could also include comments to explain their choices. Sixteen students returned their forms. I did not review the forms until later in the summer.

Next, I summarized the ideas students had conveyed to me about the course for Mary's course redesign proposal. The redesign proposal was a required part of her work as a [Collaborative] Fellow. With the summary I included a focus group transcript. The summation I sent the instructors touched on issues of course content and focus, class time activity, quiz/exam difficulty, OWLs and computer usage. I added my suggestions and explanations of students' comments also, focusing on ways to get students more active and the need to integrate formative assessment strategies into the course. My email to the instructors follows;

> Hi Mary & Liza – Here are the main issues I see the students commenting on about the course thus far – and I do not recount these with any assumption that you do not already understand these issues – and the students themselves understood the changing nature of the course as well. Again, for the sake of time, these are the main ideas, I'll speak to more about these ideas as I process them and complete the interviews, etc. Hope this helps. I've also attached an interview I conducted with 3 students, I tried to protect their anonymity and hope I succeeded - I think this will better explain some of the students' thinking – Tarin
>
> The course focused too greatly on scientific concepts/facts and not as much as the social issues surrounding DNA in our world as the students thought it would. Some students feel that the level of detail and expectations for understanding the science was beyond the interest and level of a 100 level course. A number of students who are science majors said they often drew on their knowledge from their major to make sense of the material in the course.
>
> Need more time for discussion of social issues as well as time in class to digest and reflect on the science concepts being introduced. In other words, they want small group work for general discussion as well as to "practice" the science they are learning. What that means to me is, for example, spending time each week giving students half a class period to reflect on and represent their learning (through any variety of formative assessment strategies – writing exercises, concept mapping, problem solving situations, etc). This would allow the instructor time to visit groups, ask questions, etc etc and this can be lo-tech. Or, with the enhancement of, for example, class talk, it can be more structured and perhaps more feasible for larger numbers of students (although without technology it is accomplished in the lecture class of 300 that I am also observing... students hand in a worksheet out of a notebook and TAs give them a check -, check, or check + if it is completed and turned in at the end of class...) – or students could work right in their notebooks to draw, for example, cellular structures, nucleotides, etc. – TAs and instructor could roam a lecture hall for 15 minutes during that time... you get the idea. The students want time to process what they are learning, and time to interact informally through discussion about the science as well as about issues such as stem cell research, cloning, bioengineering, behavioral genetics research, etc etc.
>
> What will this do? It engages them more, opens the dialogue more between instructor and students, forces students to think about ideas in class rather than just copying notes

and zoning out, etc etc. Also, can new information be learned this way? I think so, in some situations it can be an alternative to lecture - I'm sure there are concepts that students could work on in groups. For example, a paragraph could be written describing the structure of the cell down to the DNA – students could in groups decipher that paragraph and draw what is being described, right down to the base pairs – if a few groups were given overhead films they could show their ideas to the whole class – and the instructor could show how she makes sense of the information, etc.

Although no student (thus far) disagrees that they should be asked to think deeply and critically on the exams, many feel that they had little opportunities to solve problems or "practice" the kind of thinking required on the exams prior to the exam. This lead to a lot of frustration and feelings of incompetence. They also did not like the many answer/true false format of the exams – preferred multiple choice. I think trying a pyramid exam with the format you have now might be an interesting way to keep the format – so many students commented on how tricky the exams felt – and wondered why they had to be that way – perhaps giving short quizzes, one every 2 weeks, on the basics (like vocab and diagrams, etc)- and then 4 pyramid type exams that ask students to think more critically about situations in which the concepts are applied and evaluated would work for this population.

Lectures, OWLs, quizzes, and exams do not always seem to follow and/or complement each other. The students realize the course is under construction and simply yearned for more organization. A continuing focus on perhaps 3-5 big questions the course is trying to answer, and a continual recycling back to those questions within each lecture is a way to offer them the "road map" they seem to be looking for... Being that so many have little to know background in the subject, I think they just needed more hand holding, more clear links between this concept, this OWL, this question – during class time.

More visual aids and demonstrations would aid learning – things to touch and feel, many mentioned Nate's project presentation as an example.

Keep improving OWL – tie it in better with lecture.

Using the internet so much worried a student who did not have in home access – this student found it difficult to get assignments done and to keep up with the work – perhaps the reality of this needs to have greater focus at the beginning of the course.

Of course, so many also say the love the course, they have learned so much, they appreciate all the work and expertise that has gone into it – the interesting lectures, guest speakers, lab, movies, etc, - and keep all that.

In the last week of the semester, I also attended a [Collaborative] Fellows meeting with Mary and Liza. Fifteen "Fellows" attended the meeting with [the Collaborative] facilitators. At this meeting I was a passive observer. I wanted to attend the meeting to gain some understanding about Mary's involvement with the group. I noticed that she spoke more than other professors and often gave suggestions and summations about what was being discussed. My field notes from the meeting sum up her participation this way;

> [Mary] responded to almost all the other biology folks comments/issues. She asked questions and tried to clarify what they were describing as issues with their teaching. Not many of the other faculty did this – most just listened. She has commented that the non-participation of these meetings frustrates her. Talk is important to her. The facilitators were somewhat subdued – I think they want the faculty to take charge and make suggestions and requests for assistance. I think the faculty are tired and want guidance.

The last Introductory Genetics class of the semester ended in a unique way. Three groups of students were slotted to present their projects but only one group was prepared. As a result, Mary and Liza found themselves with forty-five minutes of unscheduled class time. Mary enthusiastically launched a class discussion by asking questions such as, "Do you think it's useful to have everyone's DNA on file?" and "Have your ideas about this changed since the beginning of the semester?" So much dialogue passed between the instructors and students during this discussion I couldn't capture it all in my notes. What I did capture, though, was the essence of what Mary and Liza had hoped for all along, that students would feel at ease enough to speak up, express opinions, and ask questions. I heard voices that day in class that I had rarely, if ever, heard before. Students were asking questions of each other, disagreeing and agreeing with the flow of ideas. There were moments of quiet while everyone gathered their thoughts on a comment that was made. There were moments of enthusiastic expression when a student had to get her point across. Two of my interviewees said it was one of the most interesting classes of the semester.

Mary closed the discussion with questions about how to inform the public about DNA and its huge impact on our society. Students offered lots of suggestions and many agreed that this course had brought them so much closer to appreciating the relevance of the DNA technology and information in their lives. "I've learned so much more than I knew before," said a female student in class that day, "I think everyone should learn this stuff!" "Yeah," said another, "now it all makes more sense."

Final Interview: Whose responsibility?

The "final interview" for this phase of the project, held a month after the last class, continued our discussion of teaching and learning. For ninety-minutes, Mary and Liza reflected on what had happened in the course and how the assisted action research project influenced their thinking over the semester. The interview highlights the tensions that hammer away at

Mary's thoughts and actions as an educator, scientist, and person in the world. These tensions impede the realization of goals and intentions for the course. First, I will summarize the issues discussed and expose their dialectical nature. Following that, I will present Mary and Liza's remarks regarding their participation in this study.

As I considered the issues of teacher change throughout this study, I was constantly struck by the those factors and situations supporting or impeding change. I will address these issues more specifically in the next chapter. Because the final interview so effectively captured the tensions affecting Mary's thoughts and actions about teaching and change, I will summarize them as a precursor to that address. Below I present six areas of tension that emerged from this interview. Some tensions existed between people (colleagues in her community, Liza, students) while others that were more pragmatic and/or ideological in nature. The tensions described below did not get resolved in this interview or in the study. Instead, conversations were begun about problems and possibilities.

Foremost to our interview discussion was Mary's resolve concerning the value of the Introductory Genetics course. At odds with that belief, however, was the tension-causing reality of time constraints and other responsibilities. Here we see Mary steadfastly believing in her efforts while at the same time casting a worried glance at her attention-hungry research program.

> ...[learning about DNA is] something that really affects people in a way that's different than lots of other kinds of things that are in the scientific realm. And that's why I think that's it's worth pushing forward to make the course the way we want it to be
>
> ...[but], if you really want the bottom line, the bottom line is that I spent way too much time on this course compared to what I should have. I'm not saying it in a negative way, it's just a fact of life – so I look at the situation with [my research] grant now, and it's going to have to be renewed in a year, and if it were up for renewal now it wouldn't be funded. And it's not like it's something personal, I've just been in this business long enough. So, we either get out 3-4 papers in the next year or I'm going to have to close the lab. But it's not a complete result of getting involved in this [course] – there are a lot of other things involved in how I spend my time and how much control I have over everyone else. I also see this course as something that has a good future and value in unto itself in the long run – so that's one reason I felt like it was an important thing to do.

Another tension that existed in the background of Mary's actions was that she felt "devalued" and unsupported by those in her community. Mary is struck by the fact that, without

Liza, this course would not be and that few others realize the effort that has been exerted to develop it.

> And working with Liza has been like icing on the cake in many ways because without her it would not have been possible. Now I say that and you say, "Yes, yes" and others say, "Yes," but they have no idea. I think that that's another way to feel undervalued in this community. I mean I feel undervalued all the time anyway so that's nothing new but the type of resource that you can have in someone like Liza, and I don't think there are a lot like you around frankly, the kind of input, the kind of support, the kind of resources, the kind of ability to actually do something, to have strength in an area that I don't – that's critical. I don't need another [Mary], I have enough problems with the ones I have. You really need another person who's going to build another part of it. And so if I have to do this myself it will be less focused on all the kind of good things that I hear in Teachnology, I hear in [the Collaborative] and all that, and come out of words like working in groups... and everything comes out of her – the fact of the matter is if I have to teach this thing alone, it will be better than this year, but it's not going to have revolutionary anythings in it because there wont' be time.

In the role of critical friend, I too was a source of tension. During the final interview, I attempted to challenge the status quo of who's in science and who's invited in by again asking Mary and Liza, "Is there a place in this course to invite students into your discipline explicitly?" I explained about a biochemistry major I had met who was considering transferring out of the major and how no introductory level courses use class time to teach students about the major and invite them to learn more. I asked, "How do we keep them in science? What brings students to choose your field?" Mary explained how each student has an advisor but doesn't always make herself known to that advisor. She explained that students transfer in and out all the time if the chemistry is too hard or if other biology domains look more appealing. On the point of inviting students into the field, she and Liza shared a similar belief, that the course itself would and should interest in students in science. Mary commented;

> I'm hoping that this is one way to try to make people think more about science – not necessarily being a research scientist – but going into areas that are related to this – and so there are students in there who are interested in things like going in to forensics and such.
>
> Tarin: And they do have an image of what they could do as science majors?
>
> M: It has to be more explicit – right... but you know the biggest problem is the way that society looks at science and scientists – and the fact that there is no exposure to being any kind of doctor except the kind they have in a hospital or a medical field and I think that's part of it.

Liza: And I think part of the problem is, if you say, I'm going to talk for a couple of minutes about [our major] – if you make it too explicit – I think you are going to lose half the students because they already know they are not going to be scientists and they are going to turn off at that point. Now maybe that's okay to lose half of the class for that 15 minutes while you are getting the other half and they are actually listening... The kind of transition you are talking about, in my mind happens because they get interested in some aspect of what you are actually doing in the class – and that makes them sort of motivated to think that, maybe I could do this – if you get them motivated in the class – if you make it doable.

Tarin: I agree with you on that – but the world of science is very closed to people who feel like they don't have a leg in it. If you look who goes into science it tends to be people who are from mid-to upper class families, someone in their family was in science, or they were always motivated to be learning, always motivated to go to the library – their options were explicitly open to them – so if you had a student who's parents didn't go to college, walking into that geology department or that biochemistry department and saying, I think I want to do this – without some hand out, or welcome, it's not as easy. Unless you have a lot of confidence. It's a unique discipline and unique place.

Another tension for Mary involved the issue that she had talked about since the beginning of the project. She questioned the value of focusing too much on teaching and course change without explicitly acknowledging students' responsibility to work hard for good grades. She wonders how much change is necessary if students do not do their part to learn.

...the problem I think is that it has a lot to do with how seriously the student takes it also. I think you can only write things down so many different ways and tell them so many different ways, if you don't read the instructions and you don't do what you supposed to do the grade suffers whether or not you've actually learned it.

We want to make the course welcoming for the students but, the fact of the matter is, that there are responsibilities and things [the students] have to do. And whether it's a level 100 course or a 600 level course, if they don't do the work then it's not – then their grade's going to suffer. And that's the name of the game so – there are 2 ways to look at school – you can look at school as a learning experience where you come away knowing all this knowledge and I think that's great and wonderful – but the fact of the matter is that it's a game – and the game is how do you get the grades.

For Mary, her belief that students were not putting in the effort to learn and/or ask for help was very confounding. Both she and Liza felt that they had worked hard to make the course interesting and welcoming so that students' would be motivated to try hard and feel comfortable asking questions. In the following excerpt from the interview, we see how Liza introduced tension into Mary's thinking about teaching and supporting students;

Mary: Now, as a professor I think it's important that I know where the students are, but there is no possible way to know everything about all of them. I think it's incumbent upon the student to take responsibility and to take action because it's not like there aren't

> resources there – not only are there us but there are the TAs – there's other ways to get assistance. We made ourselves extremely available.
>
> Liza: Then why didn't they avail themselves?
>
> Mary: I don't think that's us – I think that's them.
>
> Liza: Well, I don't know. It doesn't really matter who it is – what matters is that it's working and the fact of the matter is it didn't work! We made ourselves as available as we possibly could and we had a student who copied her paper off of the Internet rather than coming and asking a question, or 2 questions or 3 questions. I can't imagine how to make myself more available and yet, not a single student ever made an appointment with me. So, I'm not saying it's not their responsibility, I'm just saying it's broken. That aspect of it is broken. What do you do to fix it – I don't know.

Tension is not always a negative thing. In the excerpt above, we see Liza asking deeper questions of Mary about "why" things happened or did not happen. In that way, I believe, Liza brought tension to their relationship and thus attempted to stretch Mary's thinking about teaching. Mary frequently acknowledges that these challenges were important and effective at getting her to grow as an educator. Below is another example of a way that Liza "challenged" Mary's thinking.

> Mary: I think that [students don't read textbooks because] there's sort of a sense that nothing they do makes a difference, but the fact is that it does make a difference. So, somehow along the way there's a payoff, and that payoff is supposed to be pride in your own work but in the end it's also the grade in the class.
>
> Liza: The question is that the way that that student reads textbooks – does she or he absorb the information and does it make a difference in his or her exam grade?
>
> Mary: But this his or her isn't even gonna read it!
>
> Liza: But is that because in the past she's found it doesn't help her learn?

Finally, Mary points out the potential tension between Liza and herself over continued redesign of the course.

> I feel now that it's that much clearer what else to do or what to do different although I'm sure that Liza and I don't necessarily agree on where all the difficulties were and how to correct, we have a wealth of information now that we didn't have before. The framework of the course is there and now it's more like how to make that framework work better than it is to establish something that wasn't existing before. And now I have lots of ways to think about, well, we should introduce it differently, or we shouldn't...

The final interview also allowed Mary and Liza to explain the ways that they will change the course and how my interaction with them affected their thinking about teaching and learning. Mary broadly explained what changes she hoped to make and gave specifics about my intervention.

> Mary: I think there are better ways to understand what they know at the end but I think that my primary focus, having gone through it once, is to figure out the way to fix it on my end to make things be presented to the students in a different way. Not completely but there are clearly things I would do differently. And one of those is to find a better way to have a wrap up – I mean this in the problem I have every semester... [and] you having a role in this has been a godsend because from my standpoint -
>
> Tarin: I hope it hasn't been a headache! "Here she comes with her little notebook!"
>
> Mary: Don't get me started on what a headache you've been, I mean we could spend the whole hour! But I'm serious, part of me feels that we are getting information from the students that we would not normally have gotten. And we did some of our own evaluations and then there are those from the university... And other than that, and getting specific feedback from students who come by or email or whatever. I don't plan on following those specific students up other than try to do it better next time. I think that in thinking briefly, and it's been unfortunately briefly, about how I would change things I would, and even Liza and I haven't had much time to think about this together, there are places I would back off the science and push more the connections to try to make the gap between the science – which they have a harder time with and thinking about how to solve problems and things like that. And try to make the science more applicable to them and more "impactful" – is that a word?
>
> The thing you said in the beginning about professors not having the time to do the kind of interaction that you do with the students...that's not only true, in that you do it from a different perspective. Because if I meet with these students the focus is, "Are they getting the material from the class?" and what their performance was before and what it might be on the next exam. So it's perhaps more focused than the kind of interaction that you might have with them. From my standpoint, I think it's great because what you do is you provide a different perspective and if I was in... a typical situation without a [Liza], then you would be providing me with literally the only kind of outside feedback about the course that I would get. Usually, you don't get much feedback from a group of students until it's the end of the course anyway because many of them, you know, you are the professor and you are going to give them a grade and all that kind of stuff, so there's that issue. By the end of the semester, you have a feeling for the whole thing and how they felt about the whole thing. So what I felt was useful was not only your ability to interact with the students and get a feel for it – and give information to us before the end of the class which is useful because you can then try to see if there are things you can do along the way – so that's one perspective. The other thing is that in the beginning you brought up and talked about aspects of teaching that I don't think about all the time – Liza makes me do it – but if she wasn't part of it it wouldn't be that easy to do... So, the students' feedback is important... Any feedback that you give us, or interactions that we have, I find these good because they help me think about how I might do things differently and what else I want to know about.

Liza agreed that my input was important and positive to their understanding of the course, students, and potential for change. She commented;

> You are doing all this stuff for us that we don't have time to do. So the fact that we've agreed to it – I suppose there are people who would say that these meetings... where we sit and talk for an hour or two hours, "I don't have time for that!" but the fact is that it takes so much less time to do that given the information that you're funneling in to us which is so helpful and useful... that's why I jumped at the chance when you talked about it!

Our final interview ended, but our conversation continued. We talked for hours later that summer on a workshop visit to a summer program for girls in science and later that fall in meetings where they invited me to present more of my thoughts and findings. I imagine, considering the relationship we built, this conversation will never end. The next phase of the project, as the instructors make substantive changes and reflect on those efforts has begun and I continue to offer ideas and raise questions.

Summary

Webster (1988, p. 1193) defines the word tension in this way, " The act or process of stretching or the state of being stretched. A force tending to stretch something." Stretch is defined as, "To cause to extend from one place to another or across a given space" (p. 1146). The accounts of the assisted action research projects described here illustrate the myriad of ways that these professors experienced tension as they worked to act on their hopes and intentions as educators of introductory level science courses. They also highlight the ways thinking was "stretched".

In my efforts to understand the requisite conditions of the teacher change process toward an inclusive pedagogy, I placed the professors in a position to research their practice. Through a cycle of planning, acting, observing, and reflecting (Carr & Kemmis, 1986), Jim and Mary sought to understand and change elements of their practice (See Tables 17 and 18 in Appendix I). This chapter focused on my first major research question that asked how my research design helped to foster teacher change conditions.

Wenger (1998) writes "...education must strive to open new dimensions for the negotiation of self. It places students on an outbound trajectory toward a broad field of possible identities. Education is not merely formative – it is transformative" (p. 263). Through this research design, Jim and Mary were learning, being educated, about teaching. I attempted to change how they interacted with their situations – I wanted them to learn about and act on new ways of being as teachers. I hoped to further their learning of teaching and, in that way, transform their "identity-in-practice" (Lave, 1988). Following Wenger's promotion of effective learning communities, the assisted action research projects created complex social relationships that led to prolonged interaction and resolute intentions for change. By focusing on their immediate needs and issues whilst introducing feminist perspective on science education, I believe Jim and Mary were able begin to "[explore] possibilities for reinventing both [themselves] and the world around [them]" (Brickhouse, 2001, p. 289).

Throughout the projects, and especially in the final interviews, we see evidence of the projects' influences on the professors' thoughts and actions. Two weeks into the semester Jim explains how, partly as a result of our interaction, he was thinking about new issues and planning how he would teach the course again. Mary describes how our conversations bolstered her interest and motivation to learn about and act on innovative ideas offered by Liza and me. Both professors implemented new teaching strategies and/or ways to interact with students during the semester. Hopes and intentions for future changes to their courses are high.

Embedded in how I interacted with the professors throughout the projects was the data about students' impressions of the courses. Giving the students voice as the course was being developed and taught prompted fairly immediate thought and, at times, action by the professors. It offered a perspective on teaching that was novel and significant. In this way, learning about teaching emerged from the situation itself, from the professors' community of practice. By introducing and identifying the tensions and impediments to change within their situations, the professors' ways of beings as teachers, their "identities-in-practice", experienced transformation.

In the next chapter, I explore the second question of my study; How do the practical theories guiding the professors' teaching foster or impede inclusionary practice? I do this through an analysis of the nature of the aAR projects out of which I describe the Jim's and Mary's practical theories.

CHAPTER 6

INTERPRETATIONS & FINDINGS OF ASSISTED ACTION RESEARCH PROJECTS

Introduction

In Chapter Five, I demonstrated how placing the professors in a position to conduct an assisted action research project fostered teacher change. Our collaboration, with me in the roles of knowledgeable other and critical friend, provided opportunities for Jim and Mary to reflect on their thinking and activity in the courses under study, articulate their hopes and intentions, make substantive changes to their practice, and plan ways to change their teaching and course structure in the future. Tensions were rampant throughout the study as they negotiated their expectations for teaching and research with their everyday responsibilities, positions, and lives.

My methodology afforded the professors opportunities to move beyond themselves and consider broader and underlying issues guiding and constraining practice. In this chapter, I interpret the nature and findings of the assisted action research findings. I begin my analysis using the notion of the action research space (Rearick & Feldman, 1999) and end by answering my second major research question by interpreting how the professor's practical theories fostered or impeded inclusionary practice.

The aAR projects and the Action Research Space

Rearick & Feldman's (1999) construction of the action research space allows us to explore the nature of the assisted action research projects. This perspective frames action research in a three-dimensional space that encompasses the dimensions of purposes, theoretical orientation, and types of reflection. Although this characterizations risks criticism because it may misrepresent the connectedness of one's action research purpose, orientation, and reflection (Noffke, 1995; Zeichner, 1993), I find it very useful as a way to begin to understand the nature of the aAR projects. My purpose for using the action research space, and subsequent work by Feldman, Rearick, & Weiss (2001), is aligned with the authors', that is, to understand how engaging in action research projects supports or facilitates the teacher change process.

In addition, the framework allows me to set up an argument asserting the conditions of the teacher change process toward an inclusive pedagogy (my third major research question). I reach that argument by following Feldman et al.'s (2001) work, linking it with his work on practical conceptual change (2000), teaching as a way of being (1997) and aligning those findings my themes of an inclusive pedagogy (Weiss, 2001). As I proceed, I answer my second major research question; What practical theories support or impede inclusionary practices in the science classroom?

Characterizing the aAR Projects

Feldman et al. (2001) describe a study that characterizes graduate student educators', administrators', and counselors' AR projects using the action research space theoretical framework. This framework positions an action research project within three dimensions, purpose (professional, personal, political), theoretical orientation (technical, practical, and emancipatory), and type of reflection (autobiographical, collaborative, communal). We also analyzed the graduate students' AR findings using the categories of efficacy, locus of change, and moral/political agenda. These analyses, among others, allowed us to draw conclusions about the nature of the students' work. Below, I follow the same protocol; first characterizing the professor's aAR projects using the action research space theoretical framework Rearick & Feldman (1999) and then interpret the findings by applying the above-named categories.

Purpose

Feldman & Rearick describe three purposes that motivate action research; 1) a personal purpose is aimed at the understanding of self and others and the development of personal knowledge and educational theories, 2) a professional purpose seeks to add to the knowledge base for teaching or teacher development, and 3) a political purpose is critical of the sociocultural and economical nature of teachers' work and workplaces and advances a social justice-type agenda. Applying the action research space theoretical framework, we see a personal purpose for both Jim's and Mary's projects, that is, they sought to improve practice and better understand their educational situations. Improving practice meant having students demonstrate certain behaviors in class and learning on exams. Jim wanted to understand how the students regarded the course and, more specifically, how he was responding to rude talking during class. As a result, the project informed Jim of ways to modify his lectures and exam questions. During the project, he made changes to his lecture pace, amount of content covered, and expectations of student behaviors. Mary, too, sought data on students' impressions of her course and specifically wondered if she was doing too much of the talking during class. She wanted students to talk more and enacted some teaching strategies toward that goal. She continually implored students to reveal their thoughts and ideas about the course so that she could improve her practice. While Mary revealed a political purpose for creating the course (i.e. explaining that knowledge is power and wanting students to have greater access to scientific understanding for their everyday lives), she did not explicitly articulate a political purpose in the questions we investigated together.

Theoretical Orientation

One's theoretical orientation may stem from three positions; 1) a technical orientation is aimed at sense-making about one's situation through socially-constructed understandings, 2) a technical orientation situated within a need to control one's environment through actions based on rules, and 3) an emancipatory orientation is critical in nature and attempts to make explicit oppressive structures within society. The theoretical orientations of Jim's and Mary's projects were primarily technical and practical. They were technical in that their emphasis sought "to control human situations through rules based on empirical laws that govern action" (Feldman et al., 2001, p. 107). For example, Jim was worried about rude student talking and wanted to understand its effect on the class and how it could be stopped. He utilized existing "rules" and the authority of his position to attempt to remedy the student-talking problem. Mary continued asking students for input because of her belief that over time they would be comfortable with the material and would speak up more. She sought new ways to organize the lecture and classroom to overtly include students more in classroom discourse.

By collecting and/or reflecting on data about students' impressions of the course, the professors also adopted a practical theoretical orientation. Through their action and reflection, they thoughtfully and purposefully attempted to understand and characterize their situations. They adopted "rules" to explain what was going on and, in the end, questioned the applicability of their beliefs. We see this, actually, to a greater extent in Jim's case than Mary's. Jim at first believed that slowing down his lecture would cut down on student talking along with offering an early release incentive. By the end of the semester, though, he sought new understandings. He seemed to abandon his early release incentive strategy and raised questions about student interest, lack of teaching resources, necessity for greater teacher-student connections, length of lecture time, and amount of content being covered. He considered these questions in his explanation of ways to make the course more effective in the future. And, though Mary deeply considered the complex factors surrounding students' motivation and ability to engage in class discourse, she held firm to her belief that the students needed to exert greater effort and responsibility in this area. She questioned how much teacher change could make a difference in certain situations. However, relying on extrinsic motivation from her colleague Liza and myself, she acknowledged the potential beneficialness (Feldman, 1997) of new pedagogical strategies.

Types of Reflection

Action researchers engage in three types of reflection (Feldman & Rearick, 1999); 1) using autobiograhical reflection the researcher deeply explores the meaning behind the stories and explanations emanating from the project in order to understand and describe what is happening in a situation, 2) sharing stories and soliciting explanations beyond the researcher's own understandings is a type of collaborative reflection, and 3) communal reflection positions one's understandings within the contexts that support and constrain action (cultural, historical, institutional) and may develop into public discourse about issues of social justice.

Jim and Mary engaged in both autobiographical and collaborative reflection throughout the projects. Inherent in the professors' lecture and/or exam preparation was a personal examination of the curriculum and applied pedagogy. They attempted to understand and explain their practice by modifying it and considering the impact of those changes. For example, Jim's reflection motivated him to make the exams "easier", use fewer lecture slides, slow his lecture pace and teach less content. He sought out and utilized students' quotes about talking during one lecture to share his understanding of the phenomenon with the students. Jim also reflected on the course, specifically the student talking issue, with departmental colleagues who had taught the course. Mary acted in similar ways and, with of her support team, engaged often in collaborative reflection. Aspects of her course changed over time in response to how project and anecdotal data were interpreted amongst team members. During the project, lectures were modified, a new quiz format was tried, the questions and structure of OWLs assignments were constantly being redone, and team members' ideas were implemented (i.e. student presentations, field trips).

The professors also engaged in collaborative reflection with me. During our talks, Jim and Mary asked questions and articulated beliefs and concomitant theories to explain their teaching and learning situations. We attempted to interpret situations and events and shared mutual understandings. From a feminist perspective, I encouraged them to consider social and political aspects of their pedagogical and epistemological reflections. Both professors described how our talks fostered reflection and understanding of how they might change the courses over time.

Based on the above interpretation, we may characterize both professors' action research projects as somewhat "novice" or "first generation", exhibiting mainly personal purposes, technical and practical theoretical orientations, and autobiographical/collaborative types of reflection. Similar to our study (Feldman et al., 2001), the professors' assisted action research projects did not have clear or explicit political purposes, emancipatory theoretical orientations, or engage in communal reflection. Using the action research space illuminated this finding. It is important because I was originally hoping to assist the development of projects that were more transformative in nature, that is, had agendas that became more emancipatory and/or political over time.

Findings of the Projects: Efficacy, Agenda, Locus of Change

When I review the "findings" (Feldman et al., 2001) of the assisted action research projects I find results that are very similar to those in our study of graduate students and do not evolve far beyond their original purposes. Using that study's categories of efficacy (evidence that the researcher gained confidence that action research improved practice and/or theory in some way), locus of change (the people or educational situation in which the student expected change as a result of the action research) and agenda (moral or political) I examined Jim's and Mary's findings.

With respect to the category of efficacy, both Jim and Mary reported that they gained a sense of empowerment or new understanding and that the action research led to specific outcomes, such as changes in practice and effects on students. We see this the greatest in Jim's and Mary's final interviews as they describe their hopes and intentions for how they will teach the course again. For example, following an explanation of the value she placed on the data we collected during the project, Mary says:

> [Next time] there are places I would back off the science and push more the connections to try to make the gap between the science – which they have a harder time with and thinking about how to solve problems and things like that. And try to make the science more applicable to them and more "impactful"...

Jim states that:

> Next time around it will be a completely different course – completely. It will have its own identity.... It will evolve... It'll be much improved and will continue to change every time I do it.

The agenda category helps to describe the professors' moralistic intention stemming from an ethical basis that cared about students (Noddings, 1995) and sought self-improvement or professional development (Lieberman & Miller, 1984). Both professors were concerned with their students' learning and activity in class as evidenced by Jim's statement, "I guess I'm interested in knowing more about the talking issue, and if it's bothering other students..." and Mary's question, "How do I get the students more involved during class?"

I struggled with applying the locus of change category to the professors' projects. Whereas in the end, I believe that our collaborations led to changes in how they facilitated student learning and intended to teach in the future, their original goal was to change students' performance. In fact, they both identified problematic student activity as the starting points for the action research projects. And, by April, as I attempted to begin another cycle of the aAR projects based on our understandings of past issues and questions, neither professor specifically identified any new or additional questions for our research. However, at that time, their reflection on teaching was constrained by a multitude of factors and constraints described in the previous chapters. My field notes reflect this hiatus:

> I met with Mary yesterday for 45 minutes to talk about how the course was going and what was happening. She raised no new issues. She is feeling fine about the course, in general, I think... She is not experiencing "pedagogical dissonance"... (4/10)

> [Jim] seems to be coasting now, things are going more smoothly or he has accepted the situation – he is not finding anything too problematic at this time – and/or he just cannot commit the time to considering new issues. Or, of course, perhaps there is no need to. He has accepted things to be as they are... I think. (4/10)

Thus, throughout the project, at least with respect to the questions asked and action taken, the locus of change remained on the students. Feldman (2000) suggests that if we are hoping to "enact significant changes in the ways that... students participate in schooling, [educators] must go beyond a focus on the students alone to seek ways that they can change themselves or can change their education situations to facilitate change" (Feldman et al, 2000, p. 111). If our goal is for science education to transform the face of science, then the locus of change needs to be on the educator in more explicitly emancipatory and political ways. In other words, we need to foster praxis that understands and considers how to transcend the "science-as-usual" phenomena (Harding, 1991) of teacher reflection and student activity.

Yet, towards the end of the projects, I believe there was a shift away from changing students and considerations about teacher change. We see this as Jim considers how he will change his course in the future and in Mary's statements about the challenges she encountered teaching her course. Jim, in our final interview, raised questions different from those that began our work. He explained that he did not fully understand the issues surrounding inclusive teaching. Because he raised it as an issue, and based on my understanding of his way of being as a teacher, I believe that he implied a willingness to look more critically at his practice as the locus of change.

> Some of the things that always puzzled me were the gender and ethnic issues that we talked about... – but I, there were other things going on, I guess at this point my perspective is that I just try to treat everyone fairly and the same, and I don't know in science how to address some of those things...

In an email to me late in the semester, Mary wrote, "... I must admit this is really the first time in 20 years that I have found teaching to be a challenge at all." This declaration, accompanied by her deliberate questioning and interest in learning about reformist pedagogy throughout the project, also implies a compulsion toward investigating her practice as a locus of change.

In summary, using Rearick & Feldman's (1999) action research space theoretical framework, and Feldman et al's (2001) action research study, I described the nature of the professor's assisted action research projects. The projects' purposes were personal in that they sought to improve practice and better understand their educational situations, stemmed from technical and practical theoretical orientations (controlling student activity and deliberative reflection about the situations, respectively), and used autobiographical and collaborative modes of reflection. The findings of the projects show evidence that the professor's teaching efficacy was enhanced, their moral agendas were enacted, and the primary locus of change was the students. By characterizing the aAR projects in this way I have come to understand some of the practical theories guiding the professors' teaching. In the next sections, I describe the theories and deliberate on their mutability and capacity to foster or impede inclusionary practice in the science classroom using Feldman's (2000) model of practical conceptual change.

<u>Practical Conceptual Change:</u>

Researchers have found that beliefs about teaching and one's teaching situation affect pedagogy (Benson, 1989; Etchberger & Shaw; 1992; Gallagher, 1991; Hasweh, 1985; Martens, 1992; Tobin & McRobbie, 1996) and can prohibit the adoption of reformist pedagogies. (Gess-Newsome et al., 2001; Martens, 1992). Characterizing Jim's and Mary's assisted action research projects using the action research space brings up many questions about teacher change, namely, How do these descriptions aid our understanding of the teacher change process? What deeply held values and beliefs and external constraints influenced teacher change? How does the professors' status and position mediate their interest in and implementation of an inclusive pedagogy? Because this is a study of deliberation and reasoning, Feldman's (2000) model of practical conceptual change informs these questions.

Using the findings from my analysis of the aAR projects allows me to identify the practical theories, or rules-of-thumb, and "somewhat more permanent practical theories… practical paradigms" (Feldman, 2000, p. 611) that guided Jim's and Mary's decision-making. Feldman's model, which frames the teacher change process against modified conditions of conceptual change, provides a framework for consideration of these practical theories and paradigms. It also confronts the researcher with questions concerning the teacher's perspective on a change agent or intervention, that is, is the teacher discontented with a practical theory or paradigm, is the change agent or intervention comprehensible and reasonable, beneficial, and illuminating or enlightening (pp. 612-613)? An interpretation of the mutability of the professor's practical theories and paradigms is important to my study. An understanding of their resoluteness informs my second major research question; What practical theories support or impede inclusionary practices in the science classroom?

However, throughout this paper, it is necessary to reiterate the fact that Jim and Mary were teaching in novel situations and over-extending themselves with respect to available time and other commitments. Learning about teaching, which they both heartily embraced, was not factored into their faculty positions by their department heads or deans. This is not surprising, as Moscovici, (2002):

> The task of restructuring science courses can be even more complex at research universities, where the evaluation and promotion of faculty is related primarily to their research productivity. A research university often overlooks promoting and tenuring faculty on the basis of their teaching. In fact, such faculty often refer to their "teaching load", in large part because teaching requires time away from their research, which does not count for promotion and tenure (p.97).

As a result, their deliberate reflection on teaching and my ability to fully represent their ways of being as teachers was compromised. With the help of Jim and Mary conducting member checks, though, my descriptions and interpretations of their practical theories are trustworthy.

Identifying Practical Theories

Based on my analysis of the assisted action research projects using the action research space theoretical framework, we see that Jim and Mary sought answers to fairly technical problems that existed in the practical domain. Their purposes were personal. They mused about, for example, student talking (its overuse or absence) in their classrooms asking questions along the lines of, "What should be done?" (Feldman, 2000, p. 608). They took actions to change the situations using practical reasoning stemming from their moral agendas and the "context of [their] situations" (p. 609). The actions they took and our conversations about those actions helped to identify the practical theories and paradigms guiding and dictating their practice. Below

I summarize the professors' practical theories and paradigms that have relevance to my research questions. I then assess their mutability using Feldman's change terminology; discontent, comprehensible and reasonable, beneficialness, and illuminating or enlightening.

Practical Theory: Ethic of care & attitude of respect for students (Mary & Jim)

Evidence from my projects suggests that, in these settings (teaching introductory level science classes to nonmajors), Mary and Jim held a similar practical theory that may have acted as a practical paradigm. The paradigm prescribes their interactions with students. It did not waver or change throughout the project and defining it allows us to understand deeper issues surrounding their decision-making in the classroom. The paradigm is represented in the ways that Jim and Mary acted on and articulated intentions to act on an ethic of care (Noddings, 1995) and attitude of respect for their students. We see this in their efforts to understand students' thinking about their teaching and in how they interacted with students in class, through email, and during informal conversations. Also, Mary and Jim talk about how they hope to interact with students and what students' need. Neither professor exhibited discontentment with their position.

More specifically, as described in previous chapters, Mary exhibited an ethic of care and attitude of respect for her students through her intentions, use of language, and ways of interacting with them. She spoke of wanting to show students that they need not be afraid of science (12/01 meeting notes). She greeted students at the start of each class, smiled at them, and assisted students who had questions. She constantly sought students' thoughts and ideas during class and about the course in general and created an informal, encouraging learning environment. Early in the study, my student interviewees reported that she understood their learning needs and apprehensions. Later on, as students worked on their projects, Mary offered them a generous amount of individual attention, helping them wade through the research and science of their topics. During our discussions, she constantly focused on the students, describing at length her efforts to assist this student or that one, and how frustrated she was becoming with cases of ambivalence. Though Mary became frustrated with her ability and/or the situational factors that impeded her efforts to fully implement the paradigm, she never abandoned it. Even when she finally, "gave up" on students, I believe she was acting on her belief. In our final interview she said, "we did everything we could within the realm of the back and forth and the time frame to help them but they have to take a certain level of responsibility themselves and I think that's true in life and it's certainly true in college." Here we see Mary showing students care and concern by giving way for them to confront their irresponsibility and hopefully learn from it – a kind of "tough love."

Jim acted in similar ways. Evidence for this is found in how he talked about students and the actions he took in the classroom. For example, Jim explained that talking to "students one on one... is great and I love that - it's my favorite of this job...just having face time with all these great young people". He then explained how he had an "open door policy" about students coming to his office for help and advice (Phase I interview). During the semester, he sought out students' thinking and ideas about the course and his teaching. He used students' responses in one of his lectures to show them that "their voice was being taken seriously". In addition, Jim explained how he did not really expect students to speak up a lot during class because he realized that talking out in a large lecture setting was not comfortable or easy to do. My student interviewees, Luon and Alex, both described how friendly and helpful Jim was during their efforts to enroll in his over-enrolled course (Phase I interviews). "He's a really good guy", said Alex, "he helped me out so much...". And finally, we see this paradigm best as Jim expresses his frustration with the disconnect that developed between him and his students- thwarting his ability to enact his position. As with Mary, he was deeply troubled by not being able to connect with students as he was used to.

Practical Theory: Teacher- centered and curriculum-centered teaching philosophy (Mary & Jim)

A practical theory shared by Jim and Mary resulted from how expertise and authority was blended together in these settings and was enacted through a teacher and curriculum centered teaching philosophy. The theory likely guided how they taught, in general, but that is conjecture. For this setting I believe it effectively represented what they believed about teaching and learning. It also represented a normative cultural expectation of how to teach general education-type courses at the university.

Grasha (1996) bullets characteristics of this traditional teaching style, which includes that; all students can be treated alike; students are not expected to display what they know in class; teachers control the content presented, the flow of information, and how class time is spent; and teachers are not expected to get to know students on a personal level or facilitate student-student relationships. These characteristics, to varying degrees, manifested themselves in the professors' classrooms. This was most evident in the "banking model" (Freire, 1971) teaching posture they assumed that unwittingly promoted learning as knowledge acquisition (Sfard, 1998).

The learning settings were managed through structural and authoritarian means. Professors had few face-to-face discussions with students (more applicable to Jim's situation) and activities were rarely designed to compel students to share their understanding in class. Lecture presentations were a sort of performance, which if done well, should effectively transfer knowledge to the students. Both professors described their goal to clearly "distill" the content for the students. Lecture and note-taking were the predominate activities in class. Student assessments were traditional and teacher determined. However, there is also evidence showing that both Mary and Jim became discontented with aspects of this theory.

In an email to me late in the semester, Mary wrote, "... I must admit this is really the first time in 20 years that I have found teaching to be a challenge at all." Mary struggled to modify the theory, wanting to "personalize" (Grasha, 1996) her stance and what was happening in her classroom. She constantly asked students for input about how to change the course and her teaching, she asked if she "talked too much" during class time, and considered ways to foster student activity. As students began work on their projects, Mary and Liza afforded them individual attention and urged them to collaborate with them and each other.

An example of her frustration with the effort to change the activity of her classroom came following my participation in one of the Collaborative Fellows teacher meetings. After the meeting, Mary confessed angst and confusion resulting from her perceived lack of connection between the reformist teaching strategies being promoted and her practice. Whereas she intended to "guide" students more and lecture less, get to know students' learning needs and styles, incorporate more student activity and inquiry-based problems, and "empower [her] learners to show what they can do" (Grasha, 1996, p. 270), the combination of new course development, time constraints, and a belief about how to teach science to students impeded her efforts. Consequently, Mary remained steadfast in her lecturing approach throughout most of the course. In the future, she intends to modify her approach:

> I think that my primary focus having gone through it once, is to figure out the way to fix it on my end to make things be presented to the students in a different way - not completely, but there are clearly things I would do differently... (Mary, Final interview)

Modifying this practical theory was, in many ways, reasonable to Mary but extremely difficult. I do not think "how" to change it was fully comprehensible to her. Years of working successfully with more motivated science majors and graduate students offered teaching strategies and expectations of students that did not all transfer well to this setting. She was confronting deeply held beliefs about what students had to do to learn and what she had to do to teach effectively.

In my first interview with Jim, he described the ocean-related topical knowledge that he believed necessary for all students to understand and he carefully designed lecture presentations to help students make sense of the science. He sought students' opinions about the course with the intention of improving his lecture and classroom control. To control student talking, he stressed the need to "get through" a certain number of slides so that students would be prepared for the next exam. Yet, Jim became discontented with aspects of this teaching philosophy, primarily, the authoritarian role that he felt helpless to redefine or shake off.

Jim had a growing realization of the disconnect that developed between him and his students. During our discussions, he often contrasted the lecture course with smaller classes he taught, describing how they were structured around group problem-solving, discussion, and a sense of cooperation and team effort. He described aspects of the course structure he will enhance (group work) and new ways to teach the information ("lots of video") that, in the future, will remove him from center stage and hopefully better engage students.

Jim found his intended changes sensible and comprehensible. He assumed they were beneficial because they worked so well with smaller classes. He found "new understanding of a practice situation" (Feldman, 2000, p. 613) when he solicited and then incorporated students' suggestions for change into his teaching. Though his ability to implement change was constrained by a plethora of responsibility external to the teaching of this course, efforts to modify the teacher-centeredness of this teaching philosophy were enlightening. In our final interview he speaks with enthusiasm and optimism about what is possible and what should change. In contrast to Mary, though, Jim showed little evidence that he became discontented with the curriculum-centeredness of this philosophy. He did not question his role in deciding what to teach or how and when to teach it.

Practical Theory: Students will speak out more over time... (Mary)

Mary's expectations of what students had to do to learn the curriculum are part of her teaching philosophy (discussed in the previous section). One of her expectations was that, over time, students will speak out more in class and become more active. This will occur because they will become more comfortable with the scientific and technical vocabulary and the context of the words. She says;

> In the beginning it seems to be that they are going to go from being in their own little [worlds] – right now they are uncomfortable with the topic, with the idea, they are uncomfortable with this whole thing. And the first shift is that they become more comfortable asking questions and talking about things...where previously the vocabulary didn't exist.

Because Mary's expectation guided practice it acted as a practical theory. Using lecture as the primary mode of knowledge presentation, she used an "any questions?" strategy to motivate students to speak up in class. Over time, though, Mary became somewhat discontented with this practical theory. Students were not speaking up more in class and in fact, data showed that the same four - six upperclassmen were the main responders in almost every class. From mid-semester to the end of the course, my student interviewees commented about talking in class. The student data revealed issues of non-talkativeness that questioned Mary assumptions about what students knew and how comfortable they speaking up. For example, students made the following comments:

> Jane: There's no way I would've said that – I wouldn't have even known where to start to ask her to clarify things...

> Tom: So [when she's lecturing], when the train pulls out of the station you don't try to run after it and jump on...

> Annette: I remember feeling like this should be so easy, that I shouldn't be confused about this – I remember during class, it was being explained in such a way that I could see what she was talking about at the time – I could see how they went in different directions and made one little thing but I remember thinking that this seems so easy why don't I get it? I feel like I shouldn't even be asking a question because it seems like I should understand it.

Because it was becoming obvious that students were not speaking up more in class over time, Mary, Liza, and I began discussing teaching strategies to increase student activity. For example, we explored placing more emphasis on social and ethical issues related to DNA and the use of formative assessment strategies. I also suggested developing cooperative group activities that gave students opportunities to muse about issues and problems that they encountered on the quizzes and exams. Some of these ideas were new to Mary and others were not. As mentioned above, situational factors impeded her ability to find the space to develop and try out these ideas thus constraining their comprehensibility and beneficialness. However, Mary expresses her intention and willingness to implement new strategies to facilitate discussion in the future. The aAR project assisted Mary's efforts to modify this theory. She became more motivated to implement new and different strategies to foster student activity.

Practical Theory: Science is hard work... (Mary)

Stemming from the above held theories, Mary held that succeeding in science is hard work requiring students to learn from the teacher's chosen methods and take advantage of available resources in place to assist their learning. I have used many examples of this position throughout my paper. The frequency with which Mary uses this belief and how she applies it to situations involving student activity and teacher change suggest that it may have acted as a practical paradigm.

From her earliest written comments on the Phase I faculty questionnaire to the final interview, Mary reiterated her position.

> Many factors are involved [students' decisions to drop SMET majors] including poor teaching, but also poor learning/study habits on part of the students, the expectation that learning "should be" easy when it is actually hard work... (Phase I Faculty Survey)

> I don't think that's true of just this group of students – I get the feeling, I haven't taught a lot of undergraduate classes, but from my colleagues who do, over the years it seems that [not completing assignments] is becoming more and more that sort of approach to things. Probably because there is just so much material and they feel like they do what they can and if they hit it right they hit it right. (Final Interview)

> ...the problem I think is that it has a lot to do with how seriously the student takes [the work] also. I think you can only write things down so many different ways and tell them so many different ways - if you don't read the instructions and you don't do what you supposed to do the grade suffers whether or not you've actually learned it. (Final Interview)

Mary's view supports the findings of Bianchini et al. (1999) on scientists' views and instructional practices. Scientists in that study reported their beliefs that all students need to work hard, have the right attitude, and be self-motivated to succeed in science. Like the scientists in Bianchini et al.'s study, Mary's experience and anecdotal evidence from colleagues support her theory. And, although masked by her need to focus intently on course development and lecture presentation preparation, this practical theory likely guided how much change she considered reasonable.

Mary and Liza, in every class, solicited and welcomed students' questions and comments and, in the end, were not satisfied with some students' efforts to seek help and "apply" themselves. Mary's practical theory was supported by students' confessions about not doing assignments or readings. During interviews, students explained that not completing coursework made them less likely to ask questions in class because they weren't sure if they should already have learned the information. Reasons students gave for not doing the readings ran the gamut from "not sure", "didn't have time", and "it wasn't interesting" to "not needed for the exams". Thus, when Liza questions the reasons behind the students' reticence to ask for help, Mary responds, "I think that's them, not us."

While student data supported Mary's position, it countered it as well - revealing the complexity of the issue. In the beginning of the semester, my student interviewees reported feeling comfortable in class asking questions and raising issues, they enjoyed the topics and related assignments. As the semester wore on and topics became more difficult to learn, students expressed more apprehension about speaking out in class, citing that they weren't sure what to ask, if they should ask, and that is was difficult to stop Mary's lecture. They explained that assignments did not seem to mesh with lecture and weren't necessary to do because they weren't reflected on the exams. Liza suggested that perhaps one reason the students do not complete their work is that it hasn't "paid off" for them. For Mary, though, students who assume that attitude, even if it is based on past experience, are irresponsible.

Yet, as evidenced by her participation in this project, Mary is a curious and determined educator. Enacting this paradigm does not restrict her interest in learning about pedagogical strategies that could positively influence students' learning and attitudes toward science study nor her intention to give them a try.

Practical Theory: Students intrinsically interested in physical oceanography (Jim)

Another practical theory guiding Jim's practice in this course was that students are intrinsically interested in physical attributes of the oceans. This theory helps to explain the challenge in modifying his curriculum-centered teaching stance explained above. In our first interview, Jim says, "...[learning about the oceans], it's an easy sell because I think it's easy for people to be kind of into the ocean." This theory encouraged his efforts to make his lecture presentations clearer and more interesting with the addition of images and fewer words. He made these changes in response to students' varied frustrations that his slides had too many words or were changed too fast or were "boring". While many students also expressed interest in learning more about the biology of the oceans, Jim remained steadfast in his intention to teach physical oceanography. He felt that because students have access to information about marine life through the media (i.e. Discovery Channel) that this course should introduce them to information about the oceans that would assist in their understanding of current global climate change and ocean water quality issues (mid-semester discussion notes).

However, while overhauling his curriculum to infuse more socially relevant issues was not possible at this time, through our discussions he did begin to think why some curricular changes make sense. This is captured in the following exchange from a Phase II discussion (4/25) about relevancy, gatekeeping in science, and the potential for change:

> Tarin: But maybe it's in the same way that science has to sell relevance to NSF and other funding agencies-

Jim: You have to do it with students.

Tarin: Right. I think that's a bummer – I mean, we like to think that it's just intrinsically interesting...

Jim: Yeah, the romance of curiosity based science is what got me into science in the first place –

Tarin: Right, you talked about reading books and getting psyched about science.

Jim: It's so cool, you get to think about what the middle of the Earth is made of – well, that doesn't essentially impact how much the head lettuce was that I bought yesterday.

Summary: Practical Paradigms & Theories

In this section, I described some of Jim's and Mary's practical theories that "undergird[ed] and guid[ed] [their] appreciations, decisions, and actions (Sanders & McCutcheon, 1986, p.55). Two of these theories may have acted as practical paradigms; an ethic of care, concern, and respect for students and a teacher and curriculum centered teaching philosophy. These positions or stances, I believe, are deeply held and offer explanations for their thinking and activity in the classroom. The other theories described are "off-shoots" of these paradigms.

Using Feldman's model of practical conceptual change, my findings suggest that Mary's and Jim's practical paradigms resisted change even when they could not be fully implemented. Instead, they were set aside or aspects of them modified to fit the setting. Mary struggled to modify her teacher-centered and curriculum-centered teaching philosophy. She sought a philosophy that encouraged more student participation not only in the classroom but also in determining some of the content to be learned. In that way, she was rejecting more objectivist views of science teaching (Taylor et al., 2002) for constructivism. Unfortunately, the constraints of time impeded her ability to effectively explore how increasing student participation and student-selected topics/activities might allow students to construct relevant understandings about DNA. In addition, the tenaciousness of her belief that students need to work harder to be successful in science likely impacted her ability to modify aspects of her teaching.

Jim sought ways to understand his practice in order to plan how he should teach the course in the future. He upheld a curriculum-centered teaching philosophy and belief about students' interest in physical oceanography. Quickly becoming discontented with the authoritarian role his situational beliefs placed him in, he adopted new ways of interacting with students and modified aspects of his teaching methods. Jim's intentions and descriptions for how he will teach the course again reveal the reasonableness, comprehensibility, and potential beneficialness of the modification of his authoritarian role.

Research Question 2: Inclusionary Practices

Brickhouse (2001) suggests that an inclusive pedagogy "acknowledges the cultural specificity of science and empowers our students to engage in science constructively" (p. 283). Empowerment, cultural specificity, and engagement are key identifiers of my themes of inclusive pedagogy. In Chapter Two of this paper, I offer three major themes of an inclusive pedagogy; power, relevance, and discourse. Below, I reiterate the importance of those themes against the practical theories guiding Jim's and Mary's practice. Emerging from this discussion are assertions about how or if their theories fostered or impeded inclusionary practices. Their theories, at times simultaneously, enabled both inclusive and "exclusive" practices.

Attempts to balance Classroom Power

An inclusive pedagogy strives to balance power in the classroom. Teachers exhibit explicit care, interest, and concern (Noddings, 1995; Lyons, 1990; Sadker & Sadker, 1995) for their students and believe that each student has important valid contributions to make to the class discourse (Gilligan, 1990). Teachers strive to raise awareness of the sociohistorical nature of scientific knowledge (Harding, 1991; Eisenhart et al., 1996) and its evolving purposes and methodologies. Learning activities promote co-participation in the teaching, learning, and construction of scientific ideas (Taylor et al., 2002). Students are enabled (Hildebrand, 1998) and empowered as learners as they engage collaboratively with the teacher in determining learning needs, relevant topics of study, and assessment strategies (Roychoudhury et al., 1995; Mayberry & Rees, 1997).

What kind of power did the professors of my study hold and share with their students? Yukl (1989, in Moscovici, 2002) describes three categories of power used in organizations; position (formal authority or legitimate power), personal (expertise, friendship, loyalty power), and political (control over decision-making). I apply these characterizations to my participants' use of power below.

Position Power

As professors, Jim and Mary inherently held university-sanctioned position power to which students deferred. This is evident in the "collective intentionality" (Searle, 1995) of the professors and the students as they changed from a seemingly disparate group of individuals into a class, with its traditional characteristics and functions. However, "tradition dictates that students have lower status relative to the instructor… this differential begins with age difference, difference in expertise connected to the subject matter, and the salary given to teachers for their positions. There is no material reward for being a student" (Moscovici, 2002, p. 102).

The learning environments in each of my cases strongly regulated the employment of position power. The large lecture hall setting made changes to this power structure extremely difficult to imagine, let alone implement. The culture of the "large lecture hall", coupled with the introductory-science status of the course, undeniably gave Jim power over "resources, rewards, punishments, information, and environment" (Moscovici, 2002, p. 99). Students did not question their passive positions and power remained with the professor. The issue of student talkativeness, which was the focus of the aAR project, highlighted this power imbalance (Lemke, 1995).

Mary, on the other hand, taught a smaller class in a more intimate setting. In general, she "managed" the course – changing the room location, making all the announcements, chiding students to be on time, setting the pace for lecture and discussion, and determining assessment strategies and final grades. Yet, she implored students' to inform her of how she could or should alter her practice and in that way made strong attempts to share her position power. She allowed students to see her as a learner and afforded "teacher-status" to those who presented projects to the class. Liza was given opportunities to lecture and many times extrapolated on Mary's lecture topics. Teaching assistants proctored review sessions and, with Liza's assistance, designed quizzes and exams.

Mary's efforts to share position power, though, were not fully recognized. Fairly traditional modes of teaching and learning transpired for a myriad of reasons not limited to her teaching philosophy. Cultural and departmental expectations (held by the professor and students) for how introductory lecture classes should run, her inexperience teaching an introductory-level class, and her primary focus on course development most likely constrained efforts to balance power in the classroom.

Political Power

Related to position power is political power. The teacher-centered and curriculum-centered teaching philosophies underlying Jim's and Mary's practices exemplify their hold on this power. Ultimately, they held the decision-making power in these classrooms. Readings, assignments, assessment strategies, classtime activities, and how content was presented and questioned were controlled by the professors. Roth & Tobin write (2002, p.160), "The [students] became aware that performance was occurring [in the class] in which they could not take part." I think their quote captures a bit of what went on in both Mary's and Jim's class, regardless of their intentions to change it. Students' frustrations over not being able to understand a concept culminated, in part, from the expectation that they would find answers to questions they did not understand nor had opportunities to formulate.

Lemke (1990) effectively addresses issues of controlling discourse that the exercising of political power affords. Mary and Jim employed fairly traditional modes of classroom control that he describes as structural and thematic tactics. Structural tactics are ones that; determine activity boundaries, terminate discussion, control pacing, admonish "rule" breakers, and retake authority following teacher-student interaction. Thematic tactics involve asserting/marking/regulating topic irrelevancy, importance, newness, familiarity, and difficulty as well as determining when to assert expertise power, create topic "mysteries", introduce humor or get personal. We see evidences of the professors using some of these tactics and they bear heavily on the nature of discourse that occurred in their classrooms – which I will explore later in the chapter.

The position and expertise power that Jim and Mary held and acted on was undoubtedly grounded in the context of their departments that set standards and expectations of student and professor activity in classrooms. Further research is necessary to effectively tease out this external constraint on their efforts to share power.

Personal & Expertise Power

Personal power was evident in how strongly Mary and Jim desired their ethic of care and respect for students to influence relations with students. This played out differently in the classes. Unfortunately, Jim was unable to fully access his personal power as a result of the large lecture hall setting. Though students “liked him”, he was not able to motivate their learning as successfully as he could in smaller settings. Even his expertise in science was not enough to grant him personal power over students who, at times, rudely talked through his lectures. He was able to share personal power with students, though, in certain situations. When he spoke one-on-one with students the power of care and respect was shared. In addition, students were afforded personal and expertise power when they worked in groups to solve problems.

Mary’s personal power was obvious in her teaching. Her energy and passion, ability to make students laugh, and constant requests for questions and suggestions gave her power. All the students I interviewed appreciated these attributes and believed that she cared about their learning. As a result, students were motivated to learn. Students who spoke up often and talked to her outside of class shared the power of friendship and loyalty with her. Students were afforded personal and expertise power when they engaged in peer teaching during project presentations.

Here we see that Mary and Jim attempted to balance classroom power in many ways. First and foremost, they attempted to create supportive and caring learning environments. They ultimately sought meaningful interactions with their students and hoped students would not be afraid of science or using science in their everyday lives. They showed overt interest in students' ideas about their courses through the assisted action research projects. They utilized teaching strategies that afforded students some opportunities to be “experts”. Jim made steps toward non-competitiveness by allowing students to take group exams. Mary sought students’ inputs on ways to change her teaching and course structure as well as additional topics to cover. Both professors changed aspects of their teaching in response to student suggestions.

Summary: Sharing Power

My model of inclusive pedagogy asserts the importance of balancing classroom power. From that perspective, we see that exclusive practices existed in these classrooms alongside inclusionary efforts. In Jim's class, for example, position and political power manifested itself in a non-negotiable curriculum and focus on summative assessment strategies. Jim employed a practical theory of teacher and curriculum centered teaching that, by its very nature, is exclusionary to marginalized groups (Brickhouse, 1994; Davis, 1999; Harding, 1991; Rosser, 1990; Sadker & Sadker, 1994). Through fairly traditional methods, he taught students a body of pre-determined knowledge. Using technical language and concept situations unrelated to students' experiences, Jim maintained the boundaries between his community of science experts and those of novice science learners (Giroux, 1992; Roth, 1995). Students remained passive recipients of knowledge, rarely invited to share the power of expertise.

Mary's position and political power acted in more subtle but similar ways. In her course, the syllabus was more flexible topic-wise while she determined the scope and sequence of topics. Traditional summative assessments most often represented what students learned until the end of the semester when students achieved a project grade. Like Jim, her reliance on lengthy lectures or monologues (Lemke, 1995) as the primary mode of knowledge transfer situated students in passive subordinate roles even as she attempted to engage them more in the classroom.

In both cases, personal expertise power confirmed the dominant masculine image of science (Keller, 1985) and maintained the separate communities of science knowers from non-knowers (Giroux, 1992). By exposing their knowledge and oratory expertise over an ability to facilitate students' collaborations and negotiations about content, the professors unwittingly represented a masculine science through the facts and concepts, classroom interactions and activities, and assessment strategies used (AAUW, 1992; Harding, 1994; Rosser, 1990). Neither curriculum critically examined or represented the hegemonic structure and history of science. Students were expected to focus their learning on knowledge acquisition through passive and individual study and were rarely given opportunities to act as authentic users, let alone producers, of scientific knowledge (Davis, 1999; Brickhouse, 2001). Students' prior knowledge was not meaningfully accessed or utilized nor were they overtly invited to explore or consider their personal participation in science.

The aAR projects, however, highlighted and fostered the professors' dissatisfaction with aspects of the power characterizations described above. Both Jim and Mary expressed frustration with their hold on various types of power.

Strives for Relevancy

An inclusive pedagogy strives to make science relevant to the everyday and future lives of students (Lemke, 1990; Roychoudhury et al., 1995). It attempts to raise awareness about the social and historical implications of scientific endeavors (Harding, 1991) in order to critically examine the purposes of the pursuit of scientific knowledge. One goal of such an analysis is to transform the face of science by disclosing the gatekeepers that impede marginalized groups' acceptance in the scientific community of practice (Davis, 1999) and by promoting door-opening practices. Another is to change or broaden the notion of what *is* science and what science questions are important to ask. Engaging students in relevant, authentic learning situations (Lave 1992;Wenger, 1998) that promote connections with the lived experiences of females (Roychoudhury et al., 1995) and students of color (Banks, 1993) offer ways to meet those goals.

In what ways did Jim and Mary engage their students in relevant learning experiences? Did their practical theories promote or impede these efforts? We saw from the outset that both professors shared a global objective for students to be able to use the science they were learning in their everyday lives. In his first interview, Jim explains how "everybody who is a college graduate should know [about the] Earth ... and how you can actually look at that information yourself to come to some or your own conclusions about the way something works." In her first class, Mary tells her students:

> Stem cell research – lots of moral and ethical questions there. You're headed into life where DNA ... is a big deal. You need to know the issues so you can defend yourself. DNA, Genes, Chromosomes – they are important to all of us – we're trying to figure out how to make them clear to you.

Using Powerpoint presentations, short films, and computer simulations, the professors chose to teach students from a variety of resources using colorful, eye-catching images.

In Mary's class, information was presented about, for instance, cloning, DNA fingerprinting, the Human Genome Project, gene therapy, and genetically-linked diseases. Mary's students conducted a lab to isolate a section of their own DNA. For homework, the on-line tutorial-like OWL quizzes provided students with 3-D visualizations of the terms and concepts being presented in class. Textbook and a huge variety of on-line readings from over ten different sources were assigned to enhance their learning. In addition, students' first "quiz" was given to inform Mary of their prior knowledge about the content. At the end of the semester, students focused on personal topics of interest while working on their projects.

In addition, Mary made efforts to show how science was not just about content. She offered relevancy to the course in the way she portrayed herself and her team, letting students see them not just as scientists but as people with lives and families. When she introduced her course development team (including me) she described something about the person's interests. On a personal level, she spoke often of her son and his learning, her husband's and parents' work, and at times, talked about her back problems. Her son came to class twice when he was sick from school. Liza too shared personal anecdotes of her life and interests, for example, explaining to students' why, after years of teaching physical education, she pursued a doctorate in microbiology.

Mary's students appreciated her focus on teaching about relevant topics. Mid-semester, through email, I asked them what they thought of the course and what they were learning about. Students explained:

> I really enjoy the subject of DNA – I think it's very interesting. It's very relevant to what's going on now. (Annette, microbiology major)

> I learned about important issues – stuff that is going on with DNA – cloning, the Genome Project – that was really important. (Amanda, English major)

> This class covers the basic knowledge we need to know about the DNA and the applications of DNA in the modern world... (Win, computer science major)

By and large, Mary wanted her novice science learners to acquire a certain amount of declarative knowledge (Gess-Newsome, 2003) in order to define and make sense of relevant issues and their projects. She employed her practical theory of teacher and curriculum centered teaching through most, though not all, of the semester. She aided student understanding of content and relevant issues through fairly didactic teaching methods. Over time though, she began to question her attempts to assist students' development of conceptual knowledge (Gess-Newsome, 2003) and determined that they were not providing all students with the opportunities to connect with knowledge about DNA.

Mary's choice of relevant materials and how she structured students' reflection on those materials at times constrained her efforts. She often grounded relevancy within her community of practice. Students were asked to connect with topics and think about problems as scientists. Oftentimes, the result was students' perceptions that exams were getting too hard and completing all the readings was fruitless. For example, in one class she gave students an article about spider silk protein from a professional science magazine, telling them, "This is from a science magazine, it is read by scientists, I don't even always understand it. But I want you to get a feeling for how much you've really learned in the DNA world." By focusing students' sense of relevancy in the scientific world she intended to build students' confidence and validate her curricular focus. Caroline, a business major, talks about the article in the transcript below with me and Jake (final interview focus group):

> Caroline: When you have a lot of work to do you try to take the easy way out – if you don't have to do something you don't do it.
>
> Tarin: So, in your opinion those readings weren't necessary for you to do well in the exams? Was that an impression?
>
> Caroline: Yes. Well, there were some questions from the readings on the exams, but, I don't know… I can't really explain. I would read some things but then totally forget it – what the spider gene – I don't know –was that on the exam?
>
> Jake: That wasn't on the exam.

While Caroline questioned the usefulness of reading "relevant" articles, Tom, Lydia, and Heidi raised additional questions related to the theme of relevancy and connection. Tom describes his inability to connect together all the resources being offered. He felt that Mary tended to provide students with both the questions and the answers, explaining that:

> ...we get a lot of information at once and a lot of times what's covered in the lecture, what's covered in the textbook and then supplementary readings and the OWLs – all the information ties in to one another but I think it still leaves us with some questions – we never really get a chance to ask questions. (Tom)

Heidi (history major) and Lydia (sociology major) became exasperated with the technical nature of the content being presented and lack of relevance to their worlds. Lydia, who enjoyed the course and professor, and Heidi, who began the semester with enthusiasm and appreciation about the class and its supportive atmosphere, both had difficulties:

> [I thought] that [this is] the course that would help me to be able to read the newspaper or listen to NPR and know what they are talking about – follow the conversations and be able to point it out when somebody's saying something that isn't correct or following a scientific conversation. I feel like we've gone above that. ...I'm not a stupid person, and I know I can definitely know the facts but the fact is that this is brand new territory for me – and just sort of being thrusted into it and then just giving you the facts and all of sudden getting a test and then them asking a question out of nowhere that you have to put things together... it's very difficult. (Heidi)

> It's just like far out there for me because I really don't know what is going on – so I think if it's a gen ed it would have to be about like things that we use DNA for instead of the structure of DNA so much... I liked having everyone pick their own topic because, like I'm a sociology major and I'm interested in criminal justice and DNA forensics and since they didn't talk about that a whole lot I got to talk about it myself. (Lydia)

I too questioned how and if the curriculum was relevant "enough" for the students. One observation note entry (4/11) quotes Mary as saying, "That's the take home message here..." – and I scribbled, "What is? Do they really know? What does it mean to them?" And following this question from Liza, "Does this make sense? Sort of? Hopefully it will make more sense as we go on, " I wrote:

> It strikes me that there is not anything to not make sense of, they are telling, the students are copying. There is no big question the students are invested in trying to understand - they are trying to make sense of the info as it goes on, but are perhaps unsure of the importance of all the details so are not that invested in the effort? They need a question, a problem, a reason to need to know this?

As the expert, Mary knew the relevant issues surrounding her discipline. Her enactment of a teacher and curriculum centered teaching philosophy required her to make her course relevant. Her conceptual knowledge, that she so much wanted to share with her students, was born and bred within the scientific community of practice she was introduced to as a child within her parents home and as a student and scientist in future academic circles. As a result of this standpoint, her efforts to make learning relevant to nonscience majors was challenging for many reasons.

First, Brickhouse (2001) explains that meaning-making is a personal enterprise "related to who [students] are and who they want to be" (p. 286). For some of Mary's students, they chose disengagement with the subject matter because, despite her best efforts, she was unable to engage their identities. Brickhouse, citing Wenger (1998), argues that,

> ...in order for schools to be places where learning science occurs, we need to do more than just think about the content of the curriculum and pedagogies. We need to consider how learning science can change students' identities by changing their ability to participate in the world. Current educational practices... encourage... a very small range of student identities (p. 289).

Mary's students needed to participate in learning science in more ways than were being offered for most of the semester. They also needed to explicitly consider how their science learning could impact their participation in the world. Though she argued often against teaching the course to "make them scientists", Mary often validated the subjects' relevance from her community of practice, asking students to make sense of topics from a scientific and technical perspectives. Student assessment, save the projects, was based on "doing science" – that is, correctly thinking through and answering OWL, quiz, and exam questions. Many of the nonscience majors failed to find relevance because the identities linked with "doing science" were not identities they aspired to (Brickhouse, 2001).

Second, engaging students' identities in science is very difficult. In Mary's case, this was her first time teaching to nonscience majors. Her ethic of care and attitude of respect for students led to her to become discontented with her practical theory because she wanted students to have greater personal involvement with the content. However, creating effective border communities (Giroux, 1992) between her and her students' worlds confounded her. Who were these kids? What did they think? The students rarely told her. And, even when they did, through her surveys or my interjection of their voice into the aAR project, she was constrained to act for a myriad of reasons.

Finally, Mary operated under a practical theory (paradigm) that succeeding in science is hard work requiring students to learn from the teacher's chosen methods and take advantage of available resources in place to assist their learning. From the perspective of the preceding paragraphs, this theory would impede efforts to engage students' identities in science and make it relevant to their everyday and future lives. It requires students to be self-regulating learners that willingly buy into the enacted curriculum and can confidently seek answers to their confusion. Mary's graduate students and most undergraduate majors need to do this – and according to her are successful in their efforts. But the nonscience majors are not so willing or able. Many of my student participants admitted that they had not completed all the assignments and that they might have had done better if they had tried harder.

While I agree that students do not always "apply" themselves or study as hard as they should, I think Liza raised an important point. She questioned if students knew how to study and pointed out that their full course loads practically require them to shave off some assignments. Mary is unsure whose job it is to teach students why and how they should study – her's or the university's. However, even though a culture of "just get by" with respect to completing a general education courses does exist the issue is more than a question of self-regulation and motivation. It requires a broad consideration of the sociocultural and pedagogical factors that shape a student's learning identity in science and guide teacher's curriculum. Novak (1984) would interject too that meaningfully learning requires students to acquire metacognitive learning strategies that are structured into the science classroom (utilizing such learning strategies as concept mapping and vee diagramming).

Like Mary, Jim highlighted contemporary issues related to his field, informing students about such topics as global warming and the Kyoto Treaty, volcanoes and earthquakes, beach erosion, and global weather patterns. He chose in-class activities and assignments that he believed would enhance students' connection to the relevant topics being presented. Students worked cooperatively to solve workbook problems that required quantitative applications of information or sense-making about terms and concepts. Readings from the course textbook encouraged a deeper and broader understanding of the science. Students expressed interest and appreciation about his efforts to make the course relevant and were particularly vocal about his presentation on weather:

> … when [he] put up the map you know from the weather channel – I had only seen the maps but I never understood, but now I understand it so I think that way, you know, I will be watching the weather and I will understand more of what they are talking about. (Kate, Jim's class)

> The weather channel - when they have like the highs and low – I never understood that – I never paid attention because it was like a high and low and I was like OK – is it going to rain – that is what I wanted to know – and I actually know what they mean and I think it is important especially when you are watching – you watch TV – to be able to understand those things. (Sophie, Jim's class)

> I thought that was kind of cool because it was going on that day and when he talks about - showing like the map and everything and showing like the high and lows and like all these different arrows… so it was easier to stick – because I will remember that. (Cindy, Jim's class)

On specific subjects Jim made explicit connections to students' experiences and interests. For example, he told a few stories about people and their relationship with the oceans (i.e., surfers' and storm waves). During one fairly technical lecture he stopped, smiled at the students and said, "And you thought this class was all about whales and dolphins." Jim also took a minute to describe his work to the students, "What my colleagues and I look at in these sediments is the information about rainfall, climate, stream flow, and currents…" He included in his explanation issues about pollution.

As discussed in Chapter Five, however, data from the final student survey indicated that while 39% of the students agreed that they could relate what they learned in the course to their everyday lives only 14% felt that could apply what they learned to their future career. Jim's enactment of a teacher and curriculum centered teaching philosophy, as with Mary, impeded his efforts to strive for relevancy. Unlike Mary, however, he did not explicitly articulate an intention to better connect the science to students' interests and experiences. Instead, he focused on ways to enhance his presentation and student learning of the content he has chosen. Assuming that students are intrinsically interested in the ocean's physical attributes may absolve him of trying to make the course personally relevant to the everyday and future lives of students. By focusing mainly on assisting his students' acquisition of declarative knowledge he missed opportunities to foster the development of the conceptual knowledge they need to solve subject related problems in their everyday and future lives.

On the other hand, believing that students were intrinsically interested in physical attributes of the oceans kept Jim from having to focus too intently on connecting with students' interests, everyday lives, and future careers. Evidence for this argument can be found in my observations of the classes and student comments. My field notes reflect numerous comments pointing out that, for example, "here" would be a good place for Jim to ask students "x" or to elicit ideas from the business or hotel/restaurant majors about how this information might impact their future work. I have noted that there were also many places in the curriculum where Jim might have interjected stories and explanations of the baffling questions motivating his work and connected with students' sense of curiosity about real-world problems. Instead, the curriculum, more often than not, represented a very separate way of knowing and learning about science (Belenkey, et al, 1986). This is apparent in some of the email responses (4/03) I received from eight students. Five responded in the negative to my questions, "Has this course increased your interest in learning about the Earth or about science in general?" "Do you like the course? Why or why not." Students expressed the following:

> Zac: I love science and I don't think that a class could really change that, but the class is sort of boring and is not what I really expected when I took it. ...I did not really expect to spend the entire semester discussing wind, currents, and the sea floor. ... I think that the professor still needs to change the way he teaches lectures.
>
> Kate: ...often I find the material being covered extremely boring.
>
> Melissa: I don't find Oceanography to be a very interesting subject... I am not a big fan of science courses. I just don't really find things like ocean currents or sediments very interesting.
>
> Pam: I don't particularly like the course in general; I think that the subject matter is just not to my interest, and I think the lecture is partly why I don't like it either.

Lemke (1990) offers an explanation for the students' responses when he writes;

> The present curriculum is not, in my opinion, a very good one from the viewpoint of most students. At best, it represents a safe set of topics and priorities for preparing students for advanced work in science. It is mostly ... irrelevant to the uses to which most students might actually put an education in science. It is the result of finding the lowest common denominator of agreement among science researchers and fettered by historical

traditions long out of date besides. It is not a curriculum that reflects students' interest (in either sense of the word), teachers' cumulative experience and advice, or any systematic study of the life-value of its content. (p. 179)

Focuses on Discourse

Lewis & Simon (1986) analyzed the gender discourse within a college classroom. They conclude that, in order to counter a "patriarchic practice", a struggle must be waged between academic (supposedly) objective discourse, and the articulation of our everyday experiences. The adherence to that struggle manifests itself when teachers "create a space for the mutual engagement of lived difference that is not framed in oppositional terms requiring the silencing of a multiplicity of voices by a single dominant discourse"(p.469). Because science is taught through complex spoken and unspoken communications that portray its supposed extreme difficulty and specialty, science seems unattainable to the majority of students (Lemke, 1990). To focus on discourse means that teachers believe and act on the belief that each student has important valid contributions to make to the class discourse (Gilligan, 1990). They give students voice concerning what is taught, how learning occurs, and who can generate scientific knowledge (Harding, 1991; Eisenhart et al., 1996;Belenky et al., 1986; Lemke, 1990).

Mary and Jim used language in ways that sought to make their classrooms comfortable and welcoming places to learn. Because they acted on an ethic of care and attitude of respect for their students, they designed lessons to facilitate students' understanding of terminology through clear and concise definitions and examples. Students' questions and comments were always met with interest and patience. Mary used narrative monologues (Lemke, 1990) in a storied fashion, telling students, "The topic of DNA is made up of human interest stories and soap opera stories…" and she would often include stories and anecdotes in her presentations. She also used humor to keep students interest and lighten the atmosphere. For example, during a discussion about stem cells she quipped, "This is what all stem cell research is about, they could repair a lot of things. Wish they'd hurry up and do this because I'm falling apart!" Mary and Liza made explicit attempts to downplay the mystique of scientific terminology through their use of metaphors and how they guided learning during lectures.

Jim used a helping language to guide learning employing monologues that focused on making logical connections between themes, selective summaries of themes, marking themes with greater or lesser importance and maintaining a non-combative atmosphere. He would often remind students of important concepts to focus on while studying and explicitly told students what topics to or not to worry about. For example, during a lecture in March he told students, "It will pretty much guarantee an A on the exam – take a piece of paper, you should do this when you are studying, and draw these winds and label them." When he put up a slide full of words he told students, "Oh, don't worry about this stuff – too many words. We'll stick with pictures." During his monologues, he sought to retain a comfortable in class and choose fairly benign admonition responses to rude student talking (ignoring talking, general signaling for attentiveness, or stopping lecture). While intending a permissive atmosphere for students' voices in the classroom, traditional discourse language dominated the classes. Students' prior conceptions, experiences, and ways of knowing (Belenky et al., 1986; Taylor et al., 2002) were not accessed. For the most part, students were passive receivers of knowledge (Karp & Yoels, 1976), fulfilling their expected roles as note-takers and listeners. With the professors' Powerpoint slide presentations running, students were reluctant to interrupt the flow of the lecture (Macionis, 1993). Curriculum centered teaching biased classtime toward the professors' lectures and against opportunities to engage students in the expert and everyday language of science (Lemke, 1990).

Lemke argues that all types of discourse/activity that occur in the science classroom are valuable and important to understand. Because all classrooms conform to a set of rules for behavior (teacher and student), activities (such as rude talking, passive resistance, disengagement) that even traditionally considered "rule-breaking" exist within an acceptable paradigm. He argues that rule breaking does not lie outside expected social patterns but is a part of them. Also, he states that existing rules are mostly designed with the interest of the teacher in mind and that opposition to rules "reflects the differences between our interests as we see them and the interests of those who have the power to decide what 'official' rules will be" (p. 57). Importantly, he points out too that students control teacher behavior at the same time that teachers try to maintain control of the classroom. Teachers require students' cooperation to enact lessons and changes to traditional classroom practice and often meet resistance on both fronts. Students resist by declining to answer questions, enforcing pre-set agenda and discourse norms, and engaging in side-talk, disengagement, or strategies to end a lesson or class (p. 220). We see students enacting these strategies in the courses under study. The question is, "Why?"

If we accept Lemke's argument that; 1) all discourse/activity is important and a part of the social patterns of the classrooms, 2) that rule breaking occurs when, for example, students do not believe that classroom expectations promote their interests, and 3) that students not only resist traditional classroom practice but changes to that practice we begin to unpack the complex nature of discourse in the science classroom. Below, I apply these arguments to the questions Jim and Mary asked about student behavior/activity as part of the assisted action research projects.

In this paper, I have argued that both professors, while exhibiting certain characteristics of an inclusive pedagogy, for a myriad of reasons enacted a fairly traditional teaching philosophy that struggled to share power with students. Emanating from this philosophy were implicit and explicit "rules" and expectations about student behavior in the classroom. In Jim's case, a problem arose around what Lemke calls "side-talk" which occurs "any time that a student talks at all during the period without having been called on by the teacher" (p.72). The author asserts that teachers rarely uphold this as rule-breaking all the time but that it is the most frequently enforced rule. In Mary's case, I observed little side-talk, however, there was also less student participation in general that Mary hoped for.

Lemke believes that side-talk is an important part of the science classroom because it; 1) sustains students' personal relationships and is essential to the development of a "class spirit" (which promotes group dynamics), 2) fulfills students' need to communicate during class for clarification purposes of simple or logistical issues about topics or procedures and often leads to student-teacher interaction, and 3) acts as a signal to the teacher that students have become frustrated or bored if they completely disengage from the lesson. I will explore these issues more deeply within each case below.

Discourse Issues: Jim's class

Unfortunately, the majority of Jim's regular course students never or rarely spoke to him. During lecture and group activities he interacted infrequently with students. He asked questions during lecture but exhibited little wait time and rarely engaged students in more than one word responses (observation notes). In fact, except for the twenty students in the Honors section, only the students that approached him before or after class ever met him. Sierra spoke to Jim for the first time mid-way through the semester and said somewhat surprisingly, "I had to bring him a paper for missing class. I brought my paper down and he was reasonable... I remember thinking, 'Wow! He's really nice!" For Jim, the situation was frustrating:

> There were maybe five students total that I really got to know – other than the ones in the honors section. Those students got to see the real me because it was totally interactive, it was informal. We were diagram building on the blackboard together! It just was better... (Final Interview)

Jim's efforts to create a supportive and caring learning environment, which was the manifestation of his practical theory, to some degree impeded inclusionary practice. I suggest that this happened in two ways. One occurred because he did not expect students to speak out in a large lecture hall setting. Jim felt externally constrained to promote discourse because of the setting and acted on a cultural myth (Tobin & McRobbie, 1996) that relieved him of its promotion. Though students were given opportunities to discuss their learning during group activities and exams, they were afforded little opportunity to engage in discourse about their learning with him. Instead, Jim taught and made assumptions about learning similar to a physics instructor in a study conducted by Roth & Tobin (2002) who:

> In and through his inscriptions, numbers, tables, plots, best-fit curves, and sketches, he expected students to see the laws of kinematics and dynamics as part of the fundamental structure of the world. That is, he expected students to discover and understand the laws of motion through the tables with the data sets he had generated... To make students see, [he] employed inscriptions, physics talk, and talk about inscriptions. Unlike scientists, who use conversations to make sense of inscriptions, [his] presentation assumed the self-evidence of talk and inscription.

Next, for some students, inclusionary practices were impeded as a result of how Jim handled the rude talking situation. Jim's efforts to mediate rude talking were not considered effective by a number of my student interviewees. They felt that learning was negatively affected by the talking. Mid-way through the semester they expressed these concerns:

> I am not exactly sure how he should deal with the talking issue. I just wish he could find a better approach because the "talkers" don't feel bad for the students who actually want to listen. They want to get let out early so by the professor letting us out due to talkers only makes them more apt to disrupt the class. (Cindy)
>
> What is Impeding my learning?...I guess [it] is just the class atmosphere-noisy... (Pam)
>
> The only thing that is impeding my learning are the other really immature students in the class that talk ALL the time...(Sophie)

I will use Lemke's (1990) work to elucidate my position that Jim made valuable efforts to ameliorate the talking issue in very inclusive ways but was greatly impeded by the large lecture hall setting which, in concert with his teacher and curriculum centered teaching philosophy, constrained his ability to promote meaningful discourse about science in his classroom. In light of our understanding about talking in Jim's class we see that students probably engaged in side-talk for all three of Lemke's arguments for its importance. Students did know each other and often sat together to maintain relationships, they also asked each other questions about topics or the logistics of class procedures, and some completely disengaged and read the newspaper during class or discussed up-coming social events (student interviews, classroom observation notes). Jim admonished side-talk when it became clear (from his perspective and the voices of students on 1+1 response sheets) that it was disruptive to the learning process of fellow students. And, although he did use his intrinsic authority at times to squelch it (in typical but also very unique ways, such as, chasing talkers out of the lecture hall to talk to them), he also attempted a power-sharing innovation to give students' control over its occurrence. Using the words of students during a Powerpoint lecture he attempted to empower those frustrated by side-talk and connect with perpetrators' sense of compassion and fairness in order to stop it. He hoped students would/could both "police" themselves and respect each others' learning needs and not just stop side-talk because he said so. However, innovation is often met with resistance and in the large lecture hall setting I believe that effect was greatly magnified. It is to be seen if his intended course changes can effectively disrupt the disengagement-type of side-talk that affected his classroom – while he can redesign his curriculum to meet students' relevancy and discourse needs (modify content, increase group work, increase teacher-student interaction) it is questionable whether the large lecture hall learning environment can effectively be moved.

Discourse Issues: Mary's class

At the end of the semester, Mary's students talked about why they did not speak up and why the student presentations allowed for more participation:

> She talks too fast to write down the notes and goes too fast so you can't, you know... it's very hard. (Heidi)

> Well, for the presentations it's sort of student-student interaction – and when you are giving a lecture you expect to give more questions and have the students answer... versus having the students ask the questions. (Caroline)

> The information is different [during the student presentations]. With Mary presenting it's a lot of technical data so it's not like, you have a question about the material where you go, "OO, how did that protein bind again?"... In the [student] presentations, they could throw out topics and you could say, I wonder, whereas in lecture it's like – "Well, what do I wonder?" (Jake)

Some students, like Lydia and Amanda, felt that structuring in discussion in more formalized ways was necessary to motivate participation:

> Is there going to be a discussion section because I think that would work out better than this – you could meet in a discussion group outside the lecture to talk more about all these things... (Lydia)

> I talked in class sometimes, but we never had real discussions – well, maybe once or twice. More would've been good. (Amanda)

Elements of Mary's teacher and curriculum centered teaching philosophy and practical theory that students will speak up more over time as they become more comfortable with the content and classroom, impeded inclusionary practices. Taylor (Taylor et al., 2002) writes that teachers

> design innovative teaching strategies to enable students to acquire scientifically correct concepts. But classroom discussion is justified largely as a means of enabling the powerful teacher to diagnose students' understandings. Not surprisingly, classroom discussion is dominated by the voice of the question-asking, problem-posing teacher (p. 112).

Of course, all teachers gauge student learning by what they say in class, however, if students' only opportunities to speak in class were situated, as Taylor suggests, in the context of revealing what they knew or already understood it is not surprising that many kept silent. Students wanted a chance to participate differently than that, to participate in discussions that would allow them to construct understanding with their learning community (Taylor et al., 2002).

Mary's vision for how class activity should look, Liza's input, and the aAR project motivated her to disrupt the teacher-driven nature of classroom talk occurring in her classroom. She structured a Powerpoint slide to foster discussion, promoted student-student exchange around an ethical genetics question at the end of class one day, and asked one of her more informed and talkative students to hold back. With respect to the latter, she sent this email reply:

> I know it is hard for you to hold back and wait for a novice in the class to try to answer the question I have asked, but I appreciate your efforts and I think it is really important to try to involve the students more. Sometimes I am more successful at this than others!

Embedded in Mary's teacher and curriculum centered teaching philosophy and expectation that students would increase their classroom participation over time was, I believe a "rule" that students broke, that is, that students should be participate within her mode of discourse. What was her mode of discourse? I will use Lemke's notions of discourse and side-talk to further interpret the student passivity within her class.

When asking questions, Mary often utilized triadic dialogue (Lemke, 1990) to draw out students' understandings. We see this in the guided questioning transcript I present in Chapter Five (Action Plans & Outcomes). Triadic dialogue is traditional classroom dialogue that consists of a question-answer-evaluation pattern. Lemke (p. 8) portrays typical dialogue as: (following teacher preparation) there is a teacher question (that leads to the teacher calling for answers and nominating a student to respond) followed by a student answer that promotes teacher evaluation (of the students' answer and eventual teacher elaboration). He explains that this dialogue has many advantages for the teacher, that is:

> They get to initiate exchanges, set the topic, and control the direction in which the topics develops. They get to decide which students will answer which questions and to say which answers are correct. …they can even decide which answers count as the legitimate answer. In contrast, students have little or no opportunity for initiative, for controlling the direction of the discussion, or for contesting teacher prerogatives. (p. 9)

However, there is evidence that Mary did not want to hold all of this power and she actively sought ways to bring more students into the discussion and open-up student generated explorations of topics during her Powerpoint presentations. A clue to a factor that impeded her efforts comes from the side-talking issue prevalent in Jim's class – it did not exist in Mary's class. In fact, my observation notes show that students engaged in very little side-talk during even acceptable moments – the students sat quietly before class began and during changes in activity or focus (the "normal" times that side-talk erupts). In addition, during focus groups held the last week of the semester I found that students did not know each other's names. I argue that one of Lemke's functions of side talk; to sustains students' personal relationships and is essential to the development of a "class spirit" (which promotes group dynamics) was absent from the setting. Because most students did not know each other outside of class and did not develop relationships during class, little "class spirit" developed leading to students inability to engage in side-talk for clarification purposes and to try out the language of science. As a result, passivity may have, in part, resulted from their disengagement. It also may have resulted from students' resistance to her efforts to increase participation because, for one, her use of triadic dialogue made it difficult for less confident students to risk answering questions, and finally, because the students, in general, were enforcing norms of behavior in general education-type classes that allowed and promoted their passivity.

Summary: Inclusionary Practices

> "There might be times when it is appropriate to think (metaphorically) about teaching as though it involves transmitting objective facts and about learning as absorption, especially when learning efficiently by rote recall is required. At other times, we might choose to teach that facts should be regarded (metaphorically) as human constructs that are situated historically in the development of (Western) scientific ideas, and that learning is best considered as a process of constructing fallible understandings, legitimated by community agreement. (Taylor, et al, 2002, p. 203)

In this section I have described and highlighted the practical theories (and paradigms) that fostered or impeded inclusionary practices in Jim's and Mary's classes. Two practical theories, which may have acted as practical paradigms, guided much of their thinking and action as teachers. We see frustration with elements of the theories because they manifested themselves in the classroom in ways that ran counter to how the professors saw themselves as people and educators. Both wanted to connect with students and develop caring and respectful relationships. For similar and dissimilar reasons creating such connections was challenging. I argue that the teacher and curriculum centered teaching philosophy guiding their actions did not fully align with their beliefs about how they wanted to interact with their students. Gess-Newsome (2003) explains that, "Because beliefs are sensitive to the context in which they were derived, an individual may hold contradictory beliefs about similar constructs. This compartmentalization allows an individual to act in contradictory ways... (p. 5). Both Mary and Jim held a core belief about how they should interact with people and had successfully acted on that belief in past teaching situations. In these novel teaching settings, it seems that their nonscience students responded to the enactment of this theory differently than majors and graduate students and the professors began experiencing pedagogical dissonance with aspects of the theory.

Both professors, either in their reflection or actions, struggled for connections with students. They wanted to personally connect better with their students and to better connect the content to the students' everyday lives and experiences. However, an emphasis on knowledge acquisition eclipsed this need and prevented students' co-participation (Taylor et al., 2002) in the construction of science understanding. Their intentions for teaching the course again represent a commitment to improving student connections with course material and themselves.

Based on this analysis: What practical theories support or impede inclusionary practices in the science classroom? In this chapter, I identified five practical theories that Jim and Mary shared and/or were unique to their practice. Two of the theories, an ethic of care and concern and attitude of respect for students and a teacher and curriculum centered teaching philosophy continued emerging as a means to understand the professors' thinking and action in these settings. Both theories support and impede, though to different degrees, inclusionary practice. Below I focus my answer to the above question through further interpretation of these two theories.

By holding and enacting an ethic of care and concern and attitude of respect for students inclusionary practices were, for the most part, fostered. Both professors created and attempted to maintain supportive and caring learning environments. When opportunities arose, they showed overt interest in students' knowledge and ideas and were happy to commit time assisting individual students. Certain assessment and learning strategies (group work and student project presentations) were utilized that minimized the usual competitive atmosphere of the science classroom. The professors had a strong desire to make learning relevant for their students to promote understanding about the impact of the knowledge on everyday life.

While this theory has an abundance of inclusionary benefits, the way the professors applied it to their students' learning and activity may have impeded inclusion. During Jim's three hundred student lecture sections, he did not expect students to ask or answer questions because he felt that it was too much to expect: speaking out in front of crowds was difficult. As a result, he limited students' opportunities to interact with him about the content as it was being explained. Instead, he relied on group activities that, according to him, did not adequately correlate with his conceptual focus. In Mary's situation, enacting this theory in concert with her position that succeeding in science is hard work, created a sort of "tough love" philosophy in which she believed that too much overt intervention to assist students who were not trying "hard enough" was counterproductive. Students needed to learn the ramifications of their irresponsible decisions in college and in life. This stance may have limited the kind of strategies she was willing to learn about and implement.

Enacting the practical theory that espoused a teacher and curriculum centered teaching philosophy impeded inclusionary practices. The professors held most of the position, political, and personal/expertise power in the classroom which promoted student learning as knowledge acquisition and constrained student participation in knowledge construction. The professors' personal expertise power confirmed the dominant masculine image of science (Keller, 1987). By choosing to teach factual and historical scientific knowledge through fairly pedantic methods they neither critically revealed or examined the hegemonic structure and history of science. The separate community of science knowers from non-knowers was maintained (Giroux, 1992). Focusing on relevant issues and constructing meaning around them was done by the instructors - leaving students struggling to learn the science from a scientists' point of view and resulting in a separate way of knowing and learning for many of the students. Their scientific representations, grounded in the language, gestures, and inscriptions of the scientific community were uncontested by students (Roth & Tobin, 2002). Students were rarely given opportunities to practice the expert and everyday language of science (Lemke, 1990) except during lecture, which resulted in an implicit assessment of their knowledge. The majority of students likely believed their understandings to be insufficient and chose not to speak. Without student input, connections to relevant topics was difficult to maintain.

At the same time, from a feminist perspective that has an explicit political agenda toward transforming how teachers and students think about science and its connection to their work and lives, a teacher and curriculum centered teaching philosophy has inclusionary benefits. If we have a goal of "consciousness raising" as teachers, we must set some direction for our classes, choose curriculum to commence our questioning, and design experiences for our students that will lead to authentic learning (Mayberry & Rees, 1999). Martin (1994, p. 167) explains that "...one is in a better position to resist if one knows what is going on. Resistance to what one does not know is difficult, if not impossible". Scantlebury (2002) describes how, as a political act, educators must reveal the hidden curriculum that exists in order to allow women and men to transform their adherence to expected classroom roles and modes of behavior.

Both Jim and Mary had an explicit commitment to students' learning and understanding the relevance of their science. They focused student learning in that direction with the goal of empowering students to be knowledgeable and confident users of scientific information. Through the use of group work (Jim's class) and student-chosen projects/presentations (Mary's class) they afforded their students opportunities to reflect on and discuss important topics and concepts. I believe that their ability to set an agenda and design student learning experiences to guide and expose students to ways of thinking about the agenda is necessary to facilitate inclusionary practices.

Chapter Conclusion

This chapter's findings resulted from a in-depth analysis of the nature of Jim's and Mary's aAR projects that led to characterizations of the practical theories guiding their practice and the mutability of those theories followed by interpretations of the theories' ability to foster inclusionary practices in the science classroom. Often, I reminded the reader that Jim and Mary were teaching in unique situations and were afforded little support by their department to reflect on their teaching, which was what I was asking them to do. Talk, conversation, and questioning was the intervention strategy imposed upon them as they worked to make sense of what they intended students to learn and how they intended to teach to reach their goals. We did not spend endless hours discussing feminist critiques of science or debating objectivist versus social constructivist views of science. Through the aAR projects, we attempted to solve the everyday problems confronting their practice, infusing questions from a feminist standpoint when they seemed relevant and appropriate. I had an agenda, that is, wanting to expand their notion about science representation and identity (Barton, 1998) as they reflected on their actions.

My analysis portrays how a teacher and curriculum centered teaching philosophy guided their practice and that, over time, they became discontented with its manifestation in their classrooms. Mary intended to modify how she enacted the theory in order engage students more in class and connect better with their needs and interests. As she learned and learns about ways to improve her course through the aAR project she shared political power with students (by intending to utilize more of their ideas and suggestions about what and how to teach). By increasing their participation in class she hopes to share more expertise power. Jim too sought ways to share power as he became frustrated with the authoritarian role position power granted him. He utilized students' ideas to develop and validate his intentions to use more resources to teach important topics and concepts and better connect the science to students' lives.

Mary and Jim both talked about course development as an evolution. They appreciated their efficacy gains with respect to understanding students' thinking as well as potential course modifications. Even as they read this text they were reflecting on their practical theories and change issues. External constraints, however, greatly influenced and will continue to influence the professors' ability to focus on issues of teaching and learning while developing these courses. Departmental and university expectations for advancement, grant awards and recognition, institutional structures for teaching introductory level courses, the culture of university research and teaching, and family responsibilities, to name a few, bear heavily on Jim's and Mary's ability to change as teachers. Further, the dynamic interplay between their identity as scientists and their position/status within their departments, the university, and society mediated their interest in critical and feminist critiques of science and science education. In my final chapter, I will explore this dynamic and make assertions about the conditions necessary to foster the teacher change process toward an inclusive pedagogy.

CHAPTER 7

TOWARD AN INCLUSIVE PEDAGOGY: LESSONS LEARNED

Introduction

> Why do we expect good scientists - researchers, to be good teachers? Let them do their research. Let others teach. (Hedy Moscovici, personal communication)

> I've long felt that scientists who survived to be college science faculty are the ones who learned well on their own. I was this way myself. I used to study all by myself, falling in love with proofs in plane geometry, making sense of waves in physics, and learning the periodic table by inference. Since college science faculty learn this way, it is easy to assume that all people learn this way. I think that we tend to teach the way we learn, and that since most science faculty learn this way, we only reproduce other scientists who learn the same way as we do. To truly make science for all, we must recognize that others can learn in different ways than we do. We must learn from new findings from cognitive psychology and science education. As we do research in our own classrooms, we can decide what we want to do to improve the learning of our students. (Penny Gilmer in Taylor et al., 2002)

Being an effective teacher is time-consuming challenging work. In addition to having expertise in subject matter knowledge and disciplinary "know-how", it is an "an extremely complex endeavor" demanding "an adequate social and educational orientation" (Liston & Zeichner, 1991, p. 38). This requires teachers to acknowledge students' "lived biographies, cultural backgrounds, educational expectations, and previous educational experiences... [as well as] the context of schooling - the adequacy or inadequacy of their curriculum materials, building safety, the availability of supplies and other resources, school climate, school and community politics, and relationships with parents and the immediate school community" (Liston & Zeichner, 1991 from Feldman, 1997, p. 763). When I reflect upon this list and consider the busy lives of most college science faculty, I begin to agree with Hedy (above quote) – just let others teach! Gilmer (above) believes that science faculty who choose to teach are obligated to be effective educators: committed to the notion of science for all. Gilmer wants professors to research their practice and learn from the science education and cognitive psychology literature base.

Darling-Hammond (1997, p. 154) states a need for teacher change:

> If teachers are to prepare an ever more diverse group of students for much more challenging work – for framing problems; finding, integrating and synthesizing information; creating new solutions; learning on their own; and working cooperatively – they will need substantially more knowledge and radically different skills than most now have...

What knowledge? What "radically different skills"? Should science faculty acknowledge the work of educational researchers and cognitive psychologists in order to learn how to represent and transfer their knowledge to students? Should they add to their research agenda self-study and action research to improve teaching? This is truly a tall order. Why?

Because historically, science educators have implemented a pedagogy that represents the cultural norms (values, beliefs, goals) and biases of the most powerful in society (Gore, 1993). Traditional modes of knowledge transfer as pedagogy have effectively been maintained under these norms and scientists long supported as experts in teaching science. Taylor (Taylor et al., 2002, p. 240) explains:

> Students (have learned to) reason dualistically about the world; dualistic reasoning masks the creative thinking of scientists, hides the uncertainty of scientific knowledge, and robs students of their agency as self-regulating and collaborative learners. Why is it perpetuated by scientists in their teaching? Probably because it is so much easier to adopt a narrow focus on transmitting objective facts and measuring their reception via multiple-choice examinations or reproduction of model solutions.

Thus, science teaching pedagogy has not had to change for a long long time and scientific knowledge has been represented as value-free, gender-neutral, rational, and objective.

However, since the 1983 publication of a Nation at Risk, evidence is mounting that students are not effectively learning science. Miller (1991) suggests that as much as 90% of our populace is scientifically illiterate while Adey & Shayer (1994) found that 70% of adults are unable to think abstractly. In addition, feminist and critical theorists have been articulating the dispute over the knowledge claims of science – theorizing that it is subjective; constructed by the history, politics, and culture of the dominant class. Feminist critiques of science and science education have made this case loud and clear, asserting that the disconnect between how science has been historically represented and how it is constructed impedes meaningful learning of and about science as well as the goal of "science for all" (Brickhouse, 2001: Davis, 2001; Schiebinger,1999; Barton, 1998; Eisenhart et al., 1996; Harding, 1991; Delamont,1989; Haraway,1988). This discussion and suggested changes to pedagogy do not sit well with many practicing scientists who successfully mastered science through schooling and ask how knowledge production about a rock or a molecule represents cultural norms and biases - let alone fosters exclusion.

Over the last decade, educational reform in college science has attempted to not only tweak aspects of classroom activity but to transform professors' ontological and epistemological commitments to science and how they teach it. Asking them to disregard traditional modes of knowledge transfer for more student-centered approaches is grounded in a social constructivist view of scientific knowledge production. Science professors are asked to abandon long-held beliefs about power in the classroom, their roles as teachers, how they should interact with students, and what they should teach about science. As Feldman (in Weiss, Feldman, Pedevillano, Capobianco, 2002, p.18) poignantly states, "In current reform efforts we are not just asking teachers to change what they do; we are asking them to change who they are". Briscoe (2002, p. 300) explains that change is hard because "well understood contexts change as interactions among persons, things, and processes associated with the innovation take place."

Changing Who They Are

Teacher change is a fairly new area of educational research. Failed educational reform efforts from the post-Sputnik era to the 1980s revealed that teachers do not robotically implement new curriculum or accommodate new pedagogies. The newest wave of educational reform beginning in the late 1980s (AAAS, 1989, 1993, 1997; NRC, 1996) commenced the effort to offer professional development that meaningfully connected to what teachers believed about teaching and learning and how they behaved in the classroom.

Changing the practice of college science teachers is even less well understood than it is for K12 teachers. The National Science Education Standards (NRC, 1996a) includes a section on college science teaching urging professors to adopt a reformist pedagogy as does Science Teaching Reconsidered: A Handbook (NRC, 1997). In 2001, College Pathways to the Science Education Standards (NSTA) was published. It is the first publication to focus attention on change at the college level in order to link to K12 reform efforts. Promoting the use of inquiry-based activities, teaching about the history and relevant issues of science, and utilizing alternative assessment strategies within different scientific disciplines comprise the bulk of its message. In addition, the publication focuses attention on the need to effectively develop the scientific literacy of nonscience majors. With this publication it is likely that the research base surrounding college science professors' professional development will grow in the coming years. Yet, based on my study, in-depth consideration of context of college science teaching needs to play a much bigger role in how we envision the teacher change process in higher education.

My study attempted to foster teacher change through an assisted action research (aAR) project. Collaboratively, the professors and I cycled through periods of planning, acting, observing, and reflecting (Carr & Kemmis, 1986). Analysis of the change process was based on classroom actions as well as their hopes and intentions for future course implementation, and the context of their actions.

Of particular interest to me is the difference in how they responded to issues surrounding feminist critiques of science and science education. At the end of chapter Six, I wrote that "the dynamic interplay between their identity as scientists and their position/status within their departments, the university, and society mediated their interest in critical and feminist critiques of science and science education." Below, I will explore this dynamic in order to broaden my interpretation of the conditions necessary to accommodate an inclusive pedagogy. This analysis offers a frame through which to construct understanding of Jim's and Mary's interest to talk about and implement pedagogy from a more critical and feminist standpoint.

Mary developed the Introductory Genetics course for nonscience majors because she wanted to. Undoubtedly, her department wanted to increase enrollment of undergraduates taking courses, but the idea for the course began long before political issues catalyzed support. As a child and young adult, she remembers her scientist father giving talks to local groups about genetics, excited to teach them the science and make them aware of its relevance. Now, with DNA making daily headlines around the globe, she felt committed to do the same: wanting university students to understand the assured impact of the science on their everyday and future lives. She looked forward to sharing her knowledge with nonscience majors. During the aAR project, as she mused about how to effectively connect students with the science she did not easily or readily engage in conversations about feminist critiques of science or explicitly inclusive teaching strategies.

Jim, as an oceanographer, knew that his teaching responsibilities would include teaching introductory level oceanography courses to nonscience majors. He became part of a teaching rotation, assuming responsibility for teaching the course once every three or so semesters. He embraced the task – speaking excitedly about what he wanted nonscience students to learn and why the science was so important. By modifying aspects of the content and student activity he began building his own "identity" for the course. Several times during the aAR project, he brought up issues of gender equity. He expressed confusion about the topic and a desire to know more:

> So how, in a course like this, considering the material that I cover, what could I do to address this gender issue which is – what could you see... I've never gone out of my way to – I've really made it more of a nonissue – I'm just going to do the best I can at getting the information out there and I never really thought that gee, in this lecture I should talk about the contributions of women in oceanography specifically or – and I don't know if, maybe I should be doing that... (Mid-semester meeting)

> Some of the things that always puzzled me were the gender and ethnic issues that we talked about initially in the beginning – but I, there were other things going on, I guess at this point my perspective is that I just try to treat everyone fairly and the same, and I don't know in science how to address some of those things – I'm kind of at a loss... (Final Interview)

It is important to make sense of this difference for two reasons. First, assessing Mary's and Jim's inclination toward discussing, learning about, and possibly implementing an inclusive pedagogy as a result of my intervention (the aAR project) has important implications for professional development efforts with science faculty. Second, unpacking their context and our conversations about inclusion exposes both the adequacies and inadequacies of the research design and how I could have more effectively integrated the contexts of their situations with our talk to deepen our understandings and connections.

A good example of the different ways they responded to discussions of inclusiveness is found in our last interview. At that time, I reiterated my case for taking time in their introductory courses to explicitly welcome students into their departments; informing them of who goes into the major, what is required, future career options, support, and resources. They responded very differently to my suggestions. While Jim found the idea reasonable, saying,

> Jim: You're right. You could go so far as to hand out little flyers on degree programs, set up sign up sheets for advising for students who might be interested in joining a major... have you talked to Martin or Ed about this?

Mary and Liza were less receptive to the idea, either indirectly responding or questioning its benefits:

> Mary: But you know the bigger problem is the way that society looks at science and scientists – and the fact that there is no exposure to being any kind of doctor except the kind they have in a hospital or a medical field and I think that's part of, you know, all the kids know who all the sports figures are and all that so –
>
> Liza: But I think part of the problem is, if you say, I'm going to talk for a couple of minutes about – if you make it too explicit – I think you are going to lose half the students because they already know they are not going to be scientists and they are going to turn off at that point. Now maybe that's okay to lose half of the class for that 15 minutes while you are getting the other half and they are actually listening. But my thinking is that most of what you are talking about is doesn't happen... The kind of transition you are talking about, in my mind happens because they get interested in some aspect of what you are actually doing in the class – and that makes them sort of motivated to think that, maybe I could do this – if you get them motivated in the class – if you make it doable.

Throughout my data there are similar examples of Jim engaging more in conversations about equity issues than Mary. Unfortunately, I did not always follow-up their responses with good questions. Even a simple, "Tell me more," would have afforded more opportunities to explain their positions. I think, however, I did not want to push too much. Fortunately, my assessment of their contexts informs this issue.

For the reader, I begin this brief analysis by paralleling components of the professors' contexts (See Table 19 in Appendix I). In summary, Mary is a full professor and faculty member in biochemistry for twenty years. Her department is headed by a female and the predominately white faculty is and fairly evenly represented by females and males. One hundred and sixty-eight undergraduates major in biochemistry per year two-thirds of whom are white males. With biochemistry degrees, Mary states that many students go on to advanced degrees and professional careers in science (research, industry, and medicine).

Jim is an assistant professor of geology and has been on the faculty for three years. The predominately white faculty in his department is four-fifths male. Jim's department chair is also male. Seventy-five predominately white undergraduates major in geology per year with a fairly even female to male ratio. While some students with geology degrees do go on to advanced degrees and careers in industry (petroleum, environmental) or education, it is difficult to characterize the career paths of its graduates.

I believe there are key differences in professors' contexts that shaped reaction to my integration of feminist critiques of science and science education into the aAR projects, namely, the departments' mission, professors' status and position within the department, and department demographics. While differences likely hold varying levels of influence I do not explore that phenomena and suggest that is an area requiring additional research. Because the connections between the categories are fluid and dynamic, my discussion instead orders them to best represent salient connections and to only mildly infer a hierarchical structure.

Mission

The geology and biochemistry departments function under different missions with respect to the standards of achievement for student learning and how they will utilize knowledge in the future. Undergraduate biochemistry majors often have specialized career goals; medicine, industry, or research. Mary explained how students often transfer in from other majors such as biology, chemistry, or engineering to meet prerequisites for entry into certain professions. Faculty are doubly committed to students' acquisition of specialized knowledge as well as their training in the purposes and methods of biochemistry so as to function successfully in professional scientific communities. Faculty envision an integral direct link between content learning and future application. Most students enter biochemistry aware of the necessary rigor of the program. Eager to attain impressive grades on medical and/or graduate entry exams after attaining their degree, they meet expected standards or drop-out. Geology majors as a group, in general, do not move on to such specialized and competitive fields. I base this analysis on my experience as a geology major and discussions on the topic with Jim and Martin.

Majoring in geology opens doors to a multitude of occupations, many of which can be reached by majoring in other fields like engineering, environmental sciences, or marine biology. The numerous links between other majors and the geosciences allow for a more broad-based focus when it comes to departmental aims and standards. As such, the department accommodates diverse learning styles and range of interests. Students may, for example, choose a more general course of study focusing on Earth systems with an emphasis on global change, study issues related to geography and the social structures of the biosphere, or train for careers in environmental management or petroleum/mining exploration. Related to that, they may acquire empirically based procedural knowledge by studying, for example, crystallography or engage in more historical and descriptive modes of investigation using computer simulations, field work, and sample analysis.

Jim's colleague, Martin, a full professor and twenty-year veteran of the department, explained that articulating what it means to be a geology major has been an on-going negotiation amongst faculty. One main reason for this has been the change in career opportunities for majors. When there was a demand for petroleum scientists the department focused more on the training and specialized knowledge students would require to fill those positions. A similar emphasis occurred when the environmental field opened up. Now, with global change taking center stage, importance is shifting toward preparing students to understand integral links between scientific disciplines, technological applications, and societal needs. Though similarily driven by career opportunities for majors as the biochemistry department, the wide range and changing nature of those careers has created a need for geology faculty to constantly modify their program of study.

Martin pointed out that a hierarchical structure of science departments within their college negatively impacts the faculty's ability to meet the needs of a changing program. It also accounts for the department's need to accept students with a wide range of interests and academic abilities. Likely to be one of the first departments to be hit by budget cuts and operating on a smaller budget than others, it behooves his department to be accommodating to students in order to boost enrollments.

As sub-units of how society constructs understanding and status about doctors versus Earth scientists, the biochemistry and geology departments teach to, and attract, students with different interests, expectations, and needs. Because we know that enacting a pedagogy is a moral, political, and culturally-laden act (Feldman, 1997; Tobin & McRobbie, 1996; Liston & Zeichner, 1991), Mary and Jim represented science and science identity, that is, what science is made to be and who we think we must be to engage in science (Barton, 1998) using their department's socially-constructed mission as their frame of reference. Their departmental positions, status, and years as faculty members likely influenced their accommodation of departmental aims. On this subject of her department's mission, Mary was very clear. As a twenty-year veteran of the department she not only embraced its mission, she undoubtedly helped to craft it.

> But our focus is to teach students who go on into professional science – they go to medical school, they go to graduate school, they go into the biotechnology industry at the level of scientists and not in a more general category. These people have a very strong science and math background. So, as a result, our majors, they go and do great things. And ... we, of course, get ragged on because we don't have a large undergraduate population. Well, we could certainly increase our number of majors, but our argument again is that we're going to require them to take hard courses and there have to be standards – and if you flunk all these courses you can't be in this major.
>
> If you went to see a medical doctor who had gone to some easy medical school you might be real concerned about that – and I think when push comes to shove you are going to want to know that the person was trained to do what they need to do and not, well, sort of said, "Well, you tried and that's good enough". It's just not. And in science there are very high standards and very stringent criteria if you want to go on in this business...
>
> ... it's a matter of looking at it, you know, students act like science is there so you can do experiments and find out new things but in fact science is a business and going out and getting the money and hiring the people and buying the stuff and everything all that is business – it's not from some fantasy that we want to discover all this new stuff. I mean that all sounds good and is fine but in fact it's a business in the end. And the most successful labs look at it that way which is why it's so hard to compete.

Jim, on the other hand, was more vague about departmental goals for students. Perhaps the constantly developing sense of mission within the department made it difficult for him, being new, to fully grasp let alone use. Or, perhaps he was representing the dynamic nature of the department's mission that operated more through individual's acting on beliefs about how to represent science and science identity than a collective charter. For example, when asked about the department, he described more individual actions and responsibilities related to grading, course development, and reducing course load, as evidenced in the following excerpts from our final interview:

> Tarin: Within the department are grades a big deal to anybody? If everyone had gotten D in your gen ed course would you be getting flack from somebody?
>
> J: It's purely my thing.

> Tarin: So you're talking about putting together a new course, new activities, creating a homework program through Web CT – does your department give you any time for the creation of all that?
>
> Jim: No. You just have to find the time and do it.
>
> Tarin: Will your department give you have a smaller course load in the fall?
>
> Jim: It turns out that right now I teach 2 of the 3 required senior level courses for the Earth Systems major. So I can't – this is a problem that we are going to have to address as a department – if I just say, "Oh geese, I was overloaded last semester, I need some time to get some writing done, work on my research, work with my grad students, I'm taking the semester off – I can't do that right now or students get screwed.... just too much fallout would happen.

He also echoed Martin's sense that geology in general attracted more diverse learners.

> Tarin: There is stuff written that it's too scary for science departments to open themselves up that much. Because you are going to start getting, if you really go out and rally, you are going to start getting different kinds of students, and those students years later may become very creative scientists, but they are not going to quite fit the mold of what departments are used to so it's risky.
>
> Jim: I was one of those people though. I don't think I fit the mold of serious science student.

A science department's mission and professors' accommodation of its tenants filters propositions for new pedagogies. My suggestions to include a critical perspective on the science and science identities represented in Mary's course asked her to consider an emphasis not fully in line with her goals and aims for science learning. Jim found it more compelling. In a department that accommodated diverse learners and promoted a less specialized science, he found the notion of, for example, more explicit invitations into geology beneficial. Also, his career in geology was greatly due to the mentoring by one of his professors – to someone inviting in a "not very serious" science student.

<u>Position & Status</u>

Position and status influenced the professors' on this issue somewhat differently.

As a full professor and faculty member for twenty years, Mary has access to resources and information. She holds power and has a strong voice concerning what she will do, when, and why and knows where to look for funding and support for her projects. As a result, she surrounded herself with a support team to teach the genetics course. With that team she shared power and engaged in relevant discourse about teaching and learning in an apprenticeship-type style. Another reason she may have been less inclined to focus on elements of inclusion is that she was already enacting them in her practice – on one level, I wasn't telling her much that she wasn't already doing.

Jim held less power in his department. About course development, he commented that, "I would feel like I had a little bit more say once I was a tenured faculty member" (final interview) and "I'll be in a much better position next time. It'll be different when I'm tenured" (4/25). The time constraints of junior faculty paralyze their ability to act on what they believe. He agreed that his teaching assistants should play a bigger role in the course, that he could create an independent study for a student who would find resources linking course content to everyday events around the globe, and that his nonscience students could learn about the major through one of his lecture presentations. Unfortunately, he did not have the time to facilitate these actions. Instead, he tried to understand what he could do, change, and include when he taught the course again. He was interested in learning about the ways that my other participant, Mary, was able to share power and build a support team.

<u>Demographics</u>

The faculty in Jim's department is mostly male with a male department chair. Mary's department has often been chaired by females who hold more faculty positions than their geology counterparts. Not surprisingly, data representing the numbers of male and female students (including graduate students) in both departments show a higher propensity of males. Also, faculty and students are overwhelmingly Caucasian.

I did not present Jim and Mary with data tables showing departmental demographics by gender and ethnicity during our conversations. Instead, issues of equity in science were mostly confined to short stories by the professors. For example, during an international conference Jim hosted, he told me of his struggle to explain to a newspaper reporter why there were so few women in attendance. Mary, on the other hand, explained how there are more and more women entering her field. With respect to personal issues of gender, she explained that she experienced some of her first gender-related struggles when she began juggling motherhood and a career.

I do not fully understand how Jim and Mary made sense of equity issues in science. I might conjecture that Mary's history and inculcation into science in her parents' home afforded her a certain amount of "capital needed for initial entry to the science community" (Davis, 2001, p. 270) that masked the more typical struggles of females in science. We do know that the majority of females who participate in science are from families whose fathers were scientists or engineers (Schiebinger, 1999). That Jim expressed more interest in learning about issues of equity may represent the more obvious marginalization of certain groups within his field as well as issues discussed earlier about departmental mission.

Additional research is necessary to fully understand the mediating effects of departmental context on a professors' engagement with critical and feminist theories of science and science education. I suggest that in my study context did play a role and in the preceding paragraphs endeavored to explain its influence. Below, I add this discussion to my answers to my final research question.

Conditions of Teacher Change Emerging From My Study

In my study, two science professors, Jim and Mary, engaged in an assisted action research project to learn about their teaching. We engaged in a "constructivist process set in [their] social situation[s], [where their] beliefs about learning, their students, and their conceptions of themselves as learners [were] explicitly examined, challenged, and supported" (NRC, 2000, p. 199). Their goal was to better understand and improve practice - my goal was to assist them in this effort and at the foster teacher change toward an inclusive pedagogy by infusing a critical and feminist perspective into our discussions.

Using the interpretations and assessments of the professors' practice from Chapter Six and Seven, I developed assertions about the conditions necessary to foster teacher change toward an inclusive pedagogy that emerged from my study. The assertions described below are imbedded within a critical and feminist perspective that, using the assisted action research cycle, promote and engage the teacher researcher in reflection about the major themes of an inclusive pedagogy that I developed in Chapter Two (Table 6). Reflection about classroom power (Who holds the power? Can it be shared? Why should it be shared?), relevancy (What and how is science being represented? What science identities are being promoted?), and discourse issues (Who speaks? What situations promote/impede discourse? Why?) is fostered as a critical and feminist lens is used to understand problematic situations and collected data within the teacher change setting.

The assisted action research cycle (Figure 1) provides structure to my assertions. The language of practical conceptual change (discontentment, comprehensible, reasonable, beneficialness, illuminating, enlightening) (Feldman, 2000) is used to highlight the importance of understanding and characterizing how and why teachers reason about their practice.

Assertion One: Motivation for Change

Teachers learn best about new ways to teach when they are motivated or interested. In my study, both professors taught in novel settings and were at the outset interested in understanding their situations and the thoughts and impressions of their students. Their motivation to change aspects of their teaching remained high as a result of my methodological intervention (the aAR project). Our initial observations lead to their identification of problematic situations and/or areas of pedagogical discontentment. This occurred when, for example, students in Jim's class expressed frustration at how quickly he lectured - fostering his rethinking of how much content coverage was important, a re-commitment to course relevancy, and efforts to share power. In Mary's case, observational data revealed that the same students spoke in almost every class which countered her practical theory that more students would speak up over time as they became more knowledgeable about DNA and more comfortable in her classroom. A need to structure in opportunities to promote student reflection and discussion helped to motivate her interest in learning new pedagogical strategies. In both cases, reflection and planning lead to the articulation of ideas and action strategies that, if they were found to be comprehensible and reasonable, were acted upon.

Assertion Two: Active Engagement

The aAR project engaged the professors in a professional development scenario that actively engaged their thinking about complex problems confronting their everyday practice. In Phase I of the project, I attempted to understand their way of being as teachers and the constraints to their action in the classroom. Through our conversations and correspondences, I tried to create a learner-centered environment that "[built] on their strengths, interests, and needs" (NRC, 2000). Our collaboration allowed their social engagement on relevant teaching and learning issues and feminist perspectives about their practice.

As a result, Jim and Mary participated in the construction of understanding about the data we were collecting and oftentimes devised solutions that exhibited beneficialness and supported inclusionary practice. This occurred when Jim acted on the suggestion that we should solicit students' impressions about rude talking by collecting 1+1 evaluation sheets. Upon reflecting on the "who talked" issue, Mary made a personal request to a male student to hold his thoughts and questions at times in order to make space for less confident voices. Observing the ramifications of the actions lead to reflection that was collaboratively constructive and critical.

<u>Assertion Three: Opportunities to Assess Action</u>

The aAR project allowed Jim and Mary not only to devise solutions to complex problems affecting their practice, but to test out and receive feedback about their solutions (NRC, 2000). Collaboratively, we were able to determine if the actions taken were illuminating and/or enlightening. Oftentimes, reflection about action was closely tied to their experiences teaching in other settings, for example, as they considered ways to interact more personally with the introductory level students. This promoted on-going discussions about problems and solutions and plans for the future. As a result, over the course of a semester, the professors became committed to certain changes that support inclusive practice.

Examples of this can be found in how Jim handled the rude talking situation and Mary explored her role in assisting student learning. Jim devised a strategy to handle rude talking: let classes out early that listened attentively and "got through" all of his slides. Over time, however, he seemed to abandon his strategy and sought less technical solutions to the problem. As our discussion of the issue continued, he questioned the length of the lecture, the amount of content he was trying to cover, and the minimal amount of resources he utilized to teach. He became committed to planning collaborative group activities that better corresponded to his focus on relevant issues.

Mary held a practical theory that succeeding in science is hard work requiring students to learn from the teacher's chosen methods and take advantage of available resources in place to assist their learning. Over the semester, issues around students' workload, effort, and in-class activity brought her theory to the forefront. At times, Liza questioned what they were doing to assist student learning and offered explanations for students' attitudes toward "working hard". I focused on issues of relevance and how to further align the content with students' needs and interests. In the end, Mary admitted that were it not for these interactions, with Liza's "pushing" and me raising other issues, she might not be considering changes to her teaching.

Assertion Four: Critical Feminist Perspective

Though the phrase, "science for all" conjures up a diverse image of who can learn and do science, critics have exposed the biases inherent in the reform projects aimed at carrying out the proposal (Eisenhart et al., 1996: O'Loughlin, 1992, Barton, 1998; Rodriguez, 1997). As proponents of an inclusive pedagogy, we want students to not only become efficacious in their learning and doing of science but become aware of its hegemonic structure and history in order to carve out new perspectives on what it means to do science and who can participate.

Too often amongst educators, opportunities to meaningfully discuss issues of teaching and learning collapse into discussions of logistics and content. When discussions do center on the "science for all" agenda they remain routed in the current paradigm of a reformist pedagogy. Caught up in a technical rationality for using inquiry-based strategies, alternative assessments, and nature of science issues, critical considerations about the hidden curriculum that maintains scientific elitism rarely occur. My study attempted to raise a critical voice within our discussions about reforming teaching and learning. Regardless of its impact, I can fairly say that had I not brought up these issues, it is doubtful that they would have emerged at all.

Fortunately, the professors were impacted by a feminist perspective. Our discussions led Jim to raise questions about equitable teaching during our last interview and support my suggestions for explicitly inviting students into his academic major. And Mary, while not explicitly changing her practice to overtly accommodate this perspective, was satisfied in knowing that her intended course changes would benefit underrepresented groups in science.

Asserting a critical feminist perspective as a condition for teacher change also requires an assessment of the context in which change will occur. From a sociocultural perspective, generally speaking, that means gaining an understanding of the external constraints on teachers' work and the dynamic interaction of context, beliefs, and behaviors (Tobin & McRobbie, 1996; Liston & Zeichner, 1991). It requires probing deeply into the hegemonic structure of institutions to understand how power and status mediates a teacher's desire and ability to affect change. While expertise power may grant a professor status in the classroom, we know that her faculty status can constrain or support access to funds and resources. Articulating unspoken sociocultural networks influencing who can act and who cannot is integral if teachers are to accommodate an inclusive pedagogy. It also allows a broader understanding of the shared context of a professor's practical theories.

<u>Assertions Summary</u>

My assertions hold that the necessary conditions of the teacher change process toward an inclusive pedagogy require that teachers are motivated to change their practice, actively and collaboratively engage in complex problem solving about their practice, have opportunities to assess their action, and reflect on and discuss their practice from a critical feminist perspective.

I did not include in my study a knowledge component to assist the change process. While I did review Davis' (2002) model of Legitimate Participation in a Community of Practice with the professors and gave Jim a copy of former study I had conducted in the oceans course, my interjection of feminist perspectives on teaching and learning were situated in the professors' immediate needs and issues. With the constraints of time, the voluntary nature of the project, and because I followed the aims of action research I feel this was appropriate. However, I do believe that effective professional development models should include knowledge-centered learning environments (NRC, 2000) that provide teachers with a literature base and research findings to support the necessity of change toward an inclusive pedagogy. Important concepts to promote are; gender in science, constructivism, models of inquiry-based learning, formative assessment, issues in teacher change, and time management.

Implications

The most encouraging implication of this study lies in the professor's motivation to devote time and energy to the investigation of their practice. For Jim and Mary, their efforts were worth the cost. This is positive because we know that the type of teaching characterized in the NRC (1996,1997) and NSTA (2001) publications on college science teaching requires deliberate reflection on one's action (Feldman, 2000) and a change in traditional teaching methods (Tobin & McRobbie, 1996). My study bears evidence to the extent to which professors will go to learn about and improve practice.

Unfortunately, until there are changes to the structure of tenure promotion and recognition that fuel a science professor's work, studies like mine may remain isolated explorations of what is "possible". Until, for example, publications about teaching along with research count toward tenure and teaching achievements are given recognition and status within science departments, the findings herein may never be generalizable. Large reform efforts such as the Collaborative need to critically examine their goals and focus more effort on the institutional and departmental culture and structure that dictates how and where science professors should spend time. Gaining funding for curriculum transformation should be applauded and rewarded.

My study has implications for teacher change at the K16 level as it adds to the knowledge base about methodologies that effectively engage teachers in assessments about their practice and supports disclosure of their beliefs and practical theories about teaching and learning. Collaborative action research toward teacher change is an emancipatory methodology that empowers participants as it informs researchers (Lather, 1991). What is unique to my study is the emphasis placed on incorporating students' voices into our deliberations and my close association with the action of the research. As research assistant, I was a strong advocate for the students I interviewed and my in-depth understanding of the professors' context, hopes, and intentions gave me legitimacy as a critical friend.

Clearly, more research on teacher change is needed. Studies characterizing the complex struggle of science faculty to change their practice would greatly assist other researchers and interested professors in further understanding the supports and constraints to the process. This could lead to effective models for teacher change within higher education that are grounded in research and could win the support of granting agencies like NSF. A necessary prerequisite to any model would be the inclusion of discussions of teaching and learning from critical and feminist standpoints.

The researcher-teacher ratio in my study was too low to be reproduced in any larger reform effort. Therefore, other methodologies need to be developed that determine how to foster professor's reflection of their practice and support long-term engagement with the questions and issues constraining change. Assisted action research has potential in such models. The difficulty lies in creating researcher-professor relationships that allow the dynamics of change to effectively run their course. Relationships like these are based on trust, humor, compassion, and informed insight and are not to be set up lightly.

Final Thoughts

I have three related but disparate thoughts to complete this dissertation. First, I think what science professors fear most about transforming their curriculum is that it will lose its rigor and become a sort of "Sesame Street" science. Regardless of one's department, scientists deeply value the knowledge of their discipline and want students to learn about and appreciate the simple elegance of its structure. As teacher educators and promoters of reform (at any level), we need to compassionately respect that which educators hold dear. We need to find and model connections between our goals for teacher change and their epistemological commitments. No one wants science to be represented by quick images, sound bites, or furry friends singing catchy tunes – we can start from there.

Second, a lot of what this is about is representing a valid construction of the human experience. The difficulty lies in reaching consensus about the human experience and hearing from everyone's voice in that effort. We also live in a world where things have to get done and arguments need to be made about when and where all-inclusive representations are necessary.

Finally, enacting pedagogy *is* a moral and political act. Changing morals is difficult, changing politics near impossible. Yet, through dialogue and collaboration, I believe that teachers can begin to negotiate what they believe, what is possible, and what they believe is possible with, at least, the elements of an inclusive pedagogy and begin to broaden their notion of what it means to teach and learn science. Jim and Mary modeled the beginning process of critical examination and modification of how they represented science offering critical insights into their optimistic, enthusiastic, and notable efforts. They compel us to hold in high esteem the efforts of college science faculty to change how they teach.

APPENDIX A

LITERATURE REVIEW TABLES

Table 1 Oppression Definitions (from Adams, Bell, & Griffin, 1997) & Related Conceptual Issues for Research

Oppression: Pervasive Nature of Social Inequality	Conceptual Questions
1) restricting because of the "structural and material constraints" that act on a person's possibilities for the future	Why is this person here, by what means did they get here? Where will they go from here? (consider economics and networks)
2) hierarchical as a result of the privileged relationship whites have over people of color that awards members of the majority power, status, and economic gain at the cost of minority	At what cost are they here? Where else could they be? What else could they be doing? (consider classroom structure, job status)
3) a complex mix of multiple, cross cutting relationships	What type of oppression does this individual experience on a daily basis in this classroom, by those around her/him, at this institution, in this town?
4) an internalized psychological phenomenon residing in both benefactors and victims alike which offers a bizarre rationality to the existing inequality	How does this person understand her/his oppression and it origins? How do beliefs impact expectations of success or failure in a science course or career or achieving a general sense of scientific literacy?

Table 2 Key Themes of Racism, Classicism, Sexism, and "isms" (Adams, Bell, & Griffin, 1997)

Racism	1. Oppression that stigmatizes and violates the dominated group and does psychic and ethical violence to the dominated group. 2. Functions through both the conscious and unconscious thoughts and actions in order to preserve the white cultural norm
Classicism	1. Functions through structural factors and democratic capitalism to maintain the status quo and prevent considerations of alternative social and economic structures. (relies on Marxist theory) 2. Power works through the normalizing of domination relationships, which become tacit knowledge. 3. Must continuously ask "in whose interest" the system operates.
Sexism	1. Female consciousness raising groups gave opportunities for groups of women to collectively understand patriarchy and how it is manifested overtly and in their unconscious selves. Females challenged assumptions about human nature, sexuality, family life, gender roles and relations. 2. Female awareness of sexist issues lead/leads to ideas and actions for resisting and challenging inequality and the recreation of female thought and participation in the world.
Issues of Multiple "isms"	1. Critique of a unitary theory of feminism, class, race, and gender. Take into account multiple experiences of oppression of an individual. Postcolonialism and postmodernism challenge simple dualisms of black/white, heterosexual/homosexual, male/female and the essentialization groupings in a social order.

Table 3 The Social Oppression Matrix (Hardiman and Jackson, in Adams et al., 1997)

Dimension	Conceptual Definition
Context	Interacts at three levels: 1) Individual – beliefs or behaviors of an individual person and her conscious or unconscious actions or attitudes that maintain oppression 2) Institutional – family, government, industry, education, and religion institutions which shape individuals and society and can produce oppressive consequences (for example, the unequal treatment of blacks and the poor in the justice system) 3) Societal/Cultural – normalized values that bind individuals and institutions (such as philosophies of life, definitions of good, normal, health, deviance, and sickness) and provide justification for oppression
Psycho-Social Processes	Describe the conscious (knowingly supporting oppression) and/or unconscious (unknowing or naively maintained oppression) type of collusion involvement of the context levels.
Application	Describes the manifestation of oppression through attitudes and behaviors (for example, stereotypes that women can't make it in business or bypassed for a promotion and politics or an individual harassing a gay man)

Table 4 Social Identity Development Model (Hardiman and Jackson, in Adams et al., 1997)

Stage	Conceptual Definition
I: Naïve/No Social Consciousness	This stage occurs from birth to early childhood. Children act on their own needs and push boundaries that begin to reveal aspects of the social identity group – agent or target. Children feel interested in members of other groups but do not take on conscious or unconscious oppressive attitudes and behaviors. They ask questions about non-mainstream occurrences without judgement. Parents are most significant role models of social identity, along with religious groups, media, and community. As children move out of this stage they begin to understand about rules, laws, and authorities which permit certain behaviors and disallow others. They come to accept that some principles, such as freedom and equality, do not apply to everyone.
II. Acceptance	This stage represents the internalization of the dominant culture's systems of belief. They have accepted the superiority of some (agents) and the subordination of others (targets). Agents in this stage act and think appropriately unconsciously – they know what is right to do and believe. They don't consciously see inequality in society and if they do they have an unconscious system of rationalization in place to offer explanations. They see dominant culture as normative rather than themselves as privileged. They may learn about all of this covertly or overtly. For example, passive learners may blame victims for not being "normal", while active learners may be told that, "Jews are greedy, or women are dumb." Extremists in this stage may join hate or white supremacy groups. Targets in this stage have internalized messages about their inferiority by the dominant culture. They can mentally hold both these negative messages with positive messages offered by their social group. Action in this stage may reflect a passive acceptance of inferiority, as when, for example, a female only sees male doctors, votes for male politicians, or solicits male businessmen. Or action may reflect an active acceptance, when, for example, girls who are good in math do not choose engineering occupations because it is not women's work or it would be too difficult. Targets in this stage do see or accept their oppression.
III. Resistance	Agents in this stage have begun to question their dominant role in society as a result of unjust events or people that they have encountered. They shift from blaming victims for oppression to naming their agent group as the source of oppression. Examinations of the agent's own role in maintaining oppression and living a privileged life often occurs. They begin to understand how they have been shaped by society and to visualize a new identity for themselves. Targets, through a culmination of experiences, have thrown off the internalized acceptance of the dominant culture's view of their social group and may experience anger, pain, hurt and rage. They no longer believe that, for example, blacks are lazy or women are dumb as they experienced situations that disprove these stereotypes. They begin to move from the unconscious and conscious reality of "who I am not" to "who am I?" and find it difficult to mediate their new understanding within the dominant culture.

Table 4 continued on next page

TABLE 4 CONTINUED

Stage	Conceptual Definition
IV. Redefinition	AGENTS IN THIS STAGE OFTEN FEEL NEGATIVE ABOUT THEIR SOCIAL GROUP AND CONFUSED ABOUT HOW TO DEAL WITH OPPRESSION. THEY REDEFINE THEIR SOCIAL IDENTITY BY DEVELOPING A SENSE OF PRIDE IN THEIR GROUP AFTER EXAMINING SOCIALIZED INTERNALIZED DEFINITIONS OF OPPRESSION. THEY COME TO REALIZE THAT ALL GROUPS HAVE UNIQUE AND DIFFERENT VALUES TO OFFER SOCIETY AND BEGIN TO LEARN HOW THEIR INFORMED SOCIAL IDENTITY CAN BECOME A PART OF EVERYDAY LIFE. TARGETS IN THIS STAGE WORK TO REDEFINE THEMSELVES APART FROM THE PERSPECTIVE OFFERED BY DOMINANT CULTURE. THEY FORM RELATIONSHIPS WITH MEMBERS OF THEIR OWN SOCIAL IDENTITY GROUP WITH THE SAME LEVEL OF CONSCIOUSNESS AND MAY TURN AWAY FROM AGENTS WHO HAVE HELPED THEM. THE DRIVE TO RENAME THEIR SOCIAL IDENTITY IS VERY STRONG AND IS OFTEN ACCOMPLISHED THROUGH RECLAIMING THEIR HERITAGE AND SEEING THEMSELVES AS MORE THAN VICTIMS OF OPPRESSION.
V. Internalization	The goal of this stage is to extend the consciousness of one's new social identity into the unconscious attitudes and behaviors of everyday life. Agents work to think and act in spontaneously just ways with members of all groups. Targets move back into society from their supportive member groups. They may first interact with significant people in their life explicitly exposing their new self. They also begin to appreciate the oppression experienced by other groups and the oppression of their subordinates.

Table 5 Model for Curriculum Transformation for the Inclusion of Females and Men of Color in Science and Science Education (Rosser, 1997, pp. 3-4)

Stage	Description
1	Absence of women not noted. This is the traditional approach to science and the curriculum from the perspective of the white, Eurocentric, middle- to upper-class male in which the absence of women is not noted and gender affects neither who becomes a scientist or the science produced.
2	Recognition that most scientists are male and that science may reflect a masculine perspective on the physical, natural world. A few exceptional women such as Nobel laureates who have achieved the highest success as defined by the traditional standards of the discipline may be accepted in the scientific community and included in the curriculum.
3	Identification of barriers that prevent women from entering science. Women are recognized as a problem, anomaly, or absence from science and the curriculum. Women may be seen as victims, as protesters or as deprived or defective variants, who deviate form the white, middle- to upper-class norm of the male scientist.
4	Search for women scientists and their unique contributions. The extent to which the role of women has been overlook, misunderstood, or attributed to male colleagues throughout history of science is explored to determine women's scientific achievements.
5	Science done by feminists/women. In this phase, new perspectives result when women become the focus. Topics chosen for study, methods used, and language in which data and theories are described may shift and become expanded, improving the quality of science.
6	Science redefined and reconstructed to include us all.

Table 6 Elements of an Inclusive Pedagogy for Science

Attempts to balance Classroom Power (Within learning environment)	Strives for Relevancy (Curricular issues)	Focuses on Discourse (Strategies)
♦ Non-competitive learning environment	♦ Links to everyday life and careers	♦ Frequent discussions & assessments
♦ Supportive & caring learning environment: non-threatening, meaningful interactions between teacher-student & student-student	♦ Increased focus on social causes and problem-solving scenarios from traditionally female dominated fields	♦ Use of cooperative learning groups
♦ Overt teacher interest in student knowledge and ideas	♦ Opportunities to hypothesize about the effect of gender on curriculum choices and to understand the global/holistic issues and impacts of a particular topic or activity	♦ Accessing, considering, and using students' prior conceptions
♦ Open-ended curriculum with respect to content/direction & student interest/need	♦ Opportunities for personal bonding with projects (use of long-term)	♦ Practice in the expert & everyday language of science
♦ Explicitness of "science-as-usual" phenomena and its impact on marginalized communities	♦ Portrayal of female scientists and leaders in resource materials ♦ Use of inquiry based learning in student-centered environments ♦ Use of variety of resources from differing perspectives	♦ Permissive in its promotion of the female voice (opportunities to state ideas & opinions and practice asserting knowledge)
♦ Explicit invitation into field of study as a profession	♦ Manipulations with common materials (and use for data collection/problem solving activities)	♦ Opportunities to share learned content through imaginative writing & use of metaphors
♦ Variety of assessment strategies utilized: peer /oral /portfolio & performance based assessments	♦ Utilization of interesting, important and colorful objects/posters around classroom ♦ Field trips/outings/use of alternative learning environments ♦ Career information and academic counseling	♦ Use of multi-media for learning and representing student work ♦ Make explicit the dominant discourse of science ♦ Promotes student reflection and elucidation of ideas/questions

Table created by T. Weiss (2001) from the writings of Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M., 1986; Davis, K. S., 1999; Davis, K. S., 2000; Gilligan, C., 1990; Kahle, J.B. & Meece, J., 1994; Harding, S., 1991; Hildebrand, G. M., 1998; hooks, b., 1994; Lemke, J. L., 1990; Lewis, M. & Simon, R. I., 1986; Oakes, J., 1990; Rosser, S.V., 1990; Rosser, S.V. & Kelly, B., 1994; Roychoudhury, A., Tippins, D. J., & Nichols, S. E., 1995; Stewart, G. & Osborn, J., 1998; and Tobias, S., 1992..

APPENDIX B

STUDENT QUESTIONNAIRES

Student Questionnaire: Introduction to Earth's Oceans Course

♦ Your thoughts are very important - please circle the answer that best applies to you. Thanks.

1) Your college: A. Amherst B. Hampshire C. Mt. Holyoke D. Smith E. UMass F. Other

2) Gender: A. Male B. Female

3) Ethnicity: A. African-American (Non-Hispanic) B. Asian/Pacific Islander C. Caucasian/White D. Hispanic E. Native American F. Other (fill in) ______

4) Student status: A. freshman B. sophomore C. junior D. senior E. graduate F. continuing education

5) Major or area of concentration (if you are undecided, what is it likely to be?): ____________

6) What career do you hope to have? ____

7) The reason which <u>best</u> explains why I am taking this course:

A. I'm interested in this subject
B. It is a requirement for my major
C. It fulfills a general graduation requirement
D. recommended by other students
E. Other (fill in) _________

<u>Your choices for the following statements are:</u> (write chosen letter next to statement)

A. strongly agree **B**. generally agree **C**. neutral or don't know **D**. generally disagree **E**. strongly disagree

1) I expect that what I learn in this course can be applied to my everyday life.
2) I expect that what I learn in this course can be applied to my future career.
3) I think everyone should learn about the oceans and how they affect our existence.
4) I think understanding how scientists think and solve problems is useful for me to learn.
5) It is useful for me to understand how scientific theories about the oceans have developed.
6) Climate change is an important issue.
7) The oceans impact my life.
8) I am interested in learning about the oceans.

Participate in research (and earn money)

Looking for students who like and don't like science to participate in up to 2 short interviews. Will pay for your time. If interested please fill in the section below. Thank you!!

Name ________________________

Phone # ____________________ Email address ____________________

Student Questionnaire: Introductory Genetics Course

♦ **Your thoughts are very important - please circle the answer that best applies to you. Thanks.**

1 Your college: A. Amherst B. Hampshire C. Mt. Holyoke D. Smith E. UMass F. Other

2) Gender: A. Male B. Female

3 Ethnicity: A. African-American B. Asian/Pacific Islander C. Caucasian/White (Non-Hispanic) D. Hispanic E. Native American F. Other (fill in) ____________

4 Student status: A. freshman B. sophomore C. junior D. senior E. graduate F. continuing education

5 Major or area of concentration (if you are undecided, what is it likely to be?): ____________

6 What career do you hope to have? ____

<u>Your choices for the following statements are:</u> (write chosen letter next to statement)

A. strongly agree **B**. generally agree **C**. neutral or don't know **D**. generally disagree **E**. strongly disagree

1) I expect that what I learn in this course can be applied to my everyday life.
2) I expect that what I learn in this course can be applied to my future career.
3) I think everyone should learn about DNA.
4) Understanding how scientists think and solve problems is useful for me to learn.
5) It is useful for me to understand the science of how DNA works .
6) In general, I am interested in science topics.
7) My past experiences in science classes have been positive.___
8) To do well in science you have to be good at math.___
9) I am good at math.___
10) Males and females can do equally well in science.___
11) I have considered majoring in science at college.___
12) If I chose to major in science today I believe the professors would support and assist me.___
13) Scientific findings benefit all people everywhere.___

Participate in research (and earn money)

Looking for students who like and don't like science to participate in up to 2 short interviews. Will pay for your time. If interested please fill in the section below. Thank you!!

Name ________________________

Phone # __________________ Email address____________________

APPENDIX C

CONSENT TO PARTICIPATE IN RESEARCH LETTER

Title of Project: Teacher Change: A Collaborative Journey toward an Inclusive Pedagogy

Researcher: Tarin H. Weiss

Consent to Participate in a Research Study
University of Massachusetts, Amherst

The Human Studies Research Committee has approved this study and the recruitment of subjects.
Purpose: The purpose of this study is to explore and define the requisite conditions necessary to foster change in a professor's pedagogy.

Procedures: This study will take place from December 2001 – July 2002. As part of this study you will be asked to participate in interviews to answer questions related to science, science instruction, and learning. These interviews will be about 45 minutes in length, tape recorded and then transcribed. Questions may include: What is a typical day like for you? Describe your past experiences in science classes. What factors promote or impede your learning in science? A convenient time and place will be arranged for the interviews. You may also be asked to complete a brief survey. Questions in the survey will concern your beliefs about science learning and teaching. The study will also include classroom observations. A convenient day and time will be arranged for these observations. Examples of course documents will be requested.

Risks: No physical, psychological, and/or social risks are anticipated. Your anonymity will be maintained throughout the study including published or written data. Pseudonyms will be used for all participants. A general summary of the researcher's findings will be available to you upon request.

Benefits: The findings will assist science educators in the ways that they structure the content of future courses and identify the most appropriate activities to foster the science learning of their students and individuals beliefs about effective teaching.

Confidentiality: At no time will actual names of participants be used in the reporting of data collected during this study. Your anonymity will be maintained throughout the study including published or written data. Pseudonyms will be used for all participants. Interviews will be tape recorded and then transcribed; cassette tapes will be stored and labeled with only your pseudonym. Your name will be removed from your written work and replaced with a pseudonym. Names of participants will be removed from any documents collected.

Questions: If you have any questions or concerns about this study, please contact the researcher, Tarin Weiss at 227b Furcolo Hall, University of Massachusetts, Amherst, 413-545-0010 or her major advisor, Dr. Allan Feldman at 227b Furcolo Hall, University of Massachusetts, Amherst, 413-545-1570. If you have questions regarding your rights as a subject or any concerns regarding this project, you may report them to the University Human Subjects Research Committee, University of Massachusetts at 413-545-5270.

Right to Refuse or Withdraw: Participation in this study is voluntary. You may withdraw your consent and discontinue your participation at any time.
You will be given a copy of this form for your files. Your dated signature below will indicate that you have decided to volunteer as a research subject and that you have read the information provided above. Thank You!

Date Signature of Participant/Researcher

APPENDIX D

NATURE OF SCIENCE/NATURE OF TEACHING FACULTY QUESTIONNAIRE

Name: ______________________________ Date: ___________________

Please respond to the following statements using the rating scale offered below (place number after the statement):

1= strongly disagree 2= generally disagree 3= neutral or don't know
4= generally agree 5= strongly agree

In addition, feel free to make comments after any statements indicating your confusion, frustration, support of or further explanation of your response.

<u>Nature of Science</u>

1) Science is beneficial.
2) Science is competitive.
3) Science is intimidating to some.
4) Science is creative.
5) Science is Euro-centric.
6) Non-western scientific practices may be valid constructions of science.
7) Scientific knowledge develops as a result of socially constructed ideals of worthiness.
8) Scientific knowledge is constrained by funding, politics, and researcher interest.
9) The experiences, interests, and values of the scientist influence scientific research.
10) Science and society influence each other; science shapes and reflects the current cultural and political context.
11) Science is exclusive.

<u>Scientists</u>

1) Scientists investigate phenomena following an established philosophy, purpose, and methodology that is grounded in the beliefs of early European scientific societies.
2) Scientists are open-minded, logical, unbiased, and objective in their work.
3) Scientists are unique and special.
4) Anyone can become a scientist.
5) Most scientists are white males.
6) Women and minority scientists have made important contributions to science.
7) Female and male scientists enjoy equal pay, tenure status, and job placement (in industry/government/education).
8) Female and male scientists experience the workplace in the same way.

<u>Teaching Science</u>

1) My role as teacher is to present scientific knowledge during class.
2) My role as teacher is to invite students to participate in the scientific community.
3) My role as teacher is to instill a critical perspective in students about the enterprise of science in regards to who creates the knowledge and who benefits from it.
4) Students learn scientific knowledge mostly through individual study outside of class.
5) Science teachers should make learning relevant and meaningful to all students.
6) I must actively create/promote a learning environment that is supportive of male/female/ethnic/minority students equally.
7) Stereotypes about who can succeed in science may influence how I interact with students.
8) My beliefs about the nature of science influence how I teach.
9) Traditional teaching methods and course structure allow all students to succeed equally in science.
10) I am comfortable with the notion of professor/teacher acting as "coach" or "guide" during class.
11) As teacher, I am the greatest influence on a student's decision to pursue a career/interest in science.

<u>Students</u>

1) Some students cannot do science.

2) Males have more scientific abilities than females.
3) Females have not been encouraged enough in middle/high school to excel in science.
4) Students who have not excelled in high school science should probably not consider a career in science.
5) Almost anyone can understand science if she/he studies enough.
6) It is more important for certain students to spend time learning scientific facts and concepts than to spend time "behaving as scientists".
7) Females and males are enrolled in science, mathematics, engineering, and technology degree programs in roughly equal numbers.
8) Females and males drop majors in science, mathematics, engineering, and technology programs primarily because of poor teaching.
9) Succeeding in science is more difficult for females for sociocultural reasons.
10) Above all, general education students are more interested in passing the course than really learning the material.

I appreciate your thoughtful responses! Please email this back to me if you completed it on-line –

or mail it back in the self-addressed stamped envelope provided.

APPENDIX E

FACULTY INTRODUCTORY INTERVIEW PROTOCOL

Professor Name: ______________________________ Date: ___________________

Course: ____

Interviewer: _________________________. Transcribed by: __________________

Topic Domain: College/Work Focus

Tell me about your life at (the college) – what is a typical day like for you?

Covert Categories: roles, major interest, jobs, hobbies and clubs, academic likes/dislikes, present goals and activities, future goals activities

Topic Domain: Past & Present Experiences with Science

Describe how you came to be a professor at the college.

Covert categories: past/present experiences with science, in school and out of school experiences, family/mentor influences, teaching and learning experiences

Topic Domain: Introductory Level Course

Describe your hopes and intentions for the course.

Covert categories: global learning objectives, teaching objectives, teaching style, potential issues or problems, logistics of course

(Is there anything else you would like to say concerning the topics we have discussed?)

APPENDIX F

STUDENT PHASE I INTERVIEW PROTOCOL

Phase One Student Interview #1

Student Name: ______________________________ Date: ___________________

Course: ____

Professor: ____

Interviewer: _________________________ Transcribed by: _________________

Topic Domain: College/Work Focus

Tell me about your life at (the college) – what is a typical day like for you?

Covert Categories: major interest, jobs, hobbies and clubs, academic likes/dislikes, present goals and activities, future goals and activities

Topic Domain: Past & Present Experiences with Science

Describe a typical science college course you are in or have been in.

Covert categories: past/present experiences with science, in school and out of school experiences, attitudes/motivations to learn/barriers to learning, influential science people

Topic Domain: Learning

What does it mean to learn something? How does it work?

Covert categories: students' personal view of how she learns, why she does/doesn't learn, how her views of learning match her experience in science classes, why in this course, can she learn science/be a scientist, using science learning outside of class

Topic Domain: Views on the Nature of Science

Pretend someone you know is a scientist. Tell me all about them.

Covert categories: who can be a scientist, what they do, why they do it, how they work, how science changes over time, how society impacts science

APPENDIX G

SCHEDULE OF INTERACTIONS (INTRODUCTION TO EARTH'S OCEANS)

DATE	INTERACTION
2001	
29-Nov	First meeting, office, 30 minutes, discuss how project will run, etc.goals, introduction, letter of consent
21-Dec	Emailed faculty survey
2002	
19-Jan	Received faculty survey
22-Jan	Phase I interview, office, 1.5 hours, Interview protocol, discussed some of survey results, overview of study
29-Jan	Attended first class
7-Feb	Informal conversation at end of class - about using Ed's slides, can't, etc.
12-Feb	Students complete class questionnaires in Section I [I notice disconnect in class].
6-Mar	Phase I: aAR meeting in Jim's office
12-Mar	Uses blank sheet in workbook to draw global wind patterns on their own - I suggested that he use this to create his own activity
13-Mar	Jim conducts 1+1 course evaluation with students at review session
14-Mar	Discussion about student 1+1 responses, collect papers and summarize the findings
14-Mar	Email Jim information about talkativeness in other general education courses
20-Mar	Email Jim student comments from review session 1 + 1
26-Mar	Jim shows students quotes about talking in class, makes it funny, students laugh
26-Mar	Meet briefly to talk about talking issue
28-Mar	Meet briefly to talk about more course changes, he will post review session on the web, making lecture slides briefer
31-Mar	Email Jim one page information list about student majors
10-Apr	Meeting with Jim - issues: review sessions, talking, other responsibilities
10-Apr	Email Jim information. about study from AERA on jr. faculty
14-Apr	Email students requesting comments regarding course: any changes?
16-Apr	Email Jim relevancy quote from student
22-Apr	Email Jim relevancy quote from student
24-Apr	Brief discussion with Jim following lecture about tsunamis and waves
25-Apr	Phase II interview
7-May	Meet briefly to discuss talking issue
16-May	Last classroom observation
21-May	Passed out 300 end of semester student questionnaires at final exam
16-Jun	Emailed Jim 5 college website information on oceans atlas site
27-Jun	Final interview

APPENDIX H

SCHEDULE OF INTERACTIONS (INTRODUCTORY GENETICS)

DATE	INTERACTION
10/3/2001	Joined genetics team meeting- notes
11/29/2001	Joined genetics team meeting - notes
12/18/2001	Joined genetics team meeting - notes
12/21/2001	Emailed Faculty Survey
1/2/2002	Received faculty survey and summarized
7-Jan	Mary asked me to write section of Davis Grant
29-Jan	Began Classroom Observations
7-Feb	Introductory Interview Mary
11-Feb	Begin interviewing students
26-Feb	Introductory Interview Liza
12-Mar	Phase I Summary Meeting
13-Mar	Requested student comments about Owl, etc. email
25-Mar	Received student emails about OWL, etc
30-Mar	Organized and emailed student comments to Mary & Liza
9-Apr	Meeting with Mary
10-Apr	Requested student comments about Ex II, swish and spit lab, etc.
25-Apr	Phase II midmeeting about course, Collaborative involvement, etc
25-Apr	Emailed notes from Phase II midmeeting to Mary & Liza for review
26-Apr	Received Mary's comments on my meeting notes, OK
29-Apr	Received Liza's comments on my meeting notes, OK
1-May	Begin focus group interviews and individual interviews
3-May	Mary requests my ideas for getting student feedback on course
3-May	I email back suggestion of listing course components for students to comment on in written form
3-May	Mary requests update on students' comments for Collaborative course redesign proposal
5-May	Email Mary 7 main points students have commented on plus a copy of a focus group interview transcript
9-May	Final classroom observation (completed 16 observations)
16-May	Attend Collaborative Fellows meeting at 5 Colleges - notes
12-Jun	Final interview with Mary & Liza
24-Jul	Join Mary, Liza, and Mary's sister in planning for Workshop for the Women in Science Summer Camp session
29-Jul	Join Mary, Liza, and Mary's sister on trip to camp session to give workshop
11-Aug	Email request for Mary about what she would like, wish list, to be able to change N/A
20-Aug	Email request for Mary about my assertions for teacher change toward an inclusive pedagogy N/A
1-Sep	Invited to NH with Genetics team for an Elderhostel workshop
16-Oct	Meeting with Mary and Liza about lecture questions from observation notes

APPENDIX I

DATA TABLES

Table 7: Geology Department Student Enrollment

Internal Enrollment Table													
Undergraduate And Graduate Student Majors By Ethnicity and Sex Fall Semester 2000 College of Natural Sciences and Mathematics													
Department		Undergraduate						Graduate					
		Asian, Pacific Islander	Black, Non-Hispanic	Hispanic	White, Non-Hispanic	Non-Resident Alien	Non-Reporting	Asian, Pacific Islander	Hispanic	White, Non-Hispanic	Non-Resident Alien	Non-Reporting
GEOSCIENCES	Female	0	0	1	29	0	8	0	1	17	2	5
	Male	1	0	0	33	0	3	0	0	34	7	1

Note 1: Race/Ethnicity is based upon students' voluntary self report
Note 2: Students are counted according to the location of their primary major.
(Source: University Office of Institutional Research)

Table 8: Phase I Faculty Questionnaire Data: Jim

Strongly Disagrees (1)	Generally Disagree (2)	Neutral or Don't Know (3)	Generally Agree (4)	Strongly Agree (5)
1 Females and males are enrolled in science, mathematics, engineering, and technology degree programs in roughly equal numbers. (?) 1 Males have more scientific abilities than females. 1 Traditional teaching methods and course structure allow all students to succeed equally in science	2 3Scientific knowledge is constrained by funding, politics, and researcher interest. 2 Above all, general education students are more interested in passing the course than really learning the material. 2 Female and male scientists enjoy equal pay, tenure status, and job placement (in industry/government/education). (added "?") 2 Scientific knowledge develops as a result of socially constructed ideals of worthiness. 2 Scientists investigate phenomena following an established philosophy, purpose, and methodology that is grounded in the beliefs of early European scientific societies. 2 Some students cannot do science. 2 Stereotypes about who can succeed in science may influence how I interact with students.	3 4Females and males drop majors in science, mathematics, engineering, and technology programs primarily because of poor teaching. (?) 3 4Non-western scientific practices may be valid constructions of science. 3 4Students learn scientific knowledge mostly through individual study outside of class. 3 Almost anyone can understand science if she/he studies enough. (didn't answer) 3 Anyone can become a scientist. (depends on definition of "scientist") 3 As teacher, I am the greatest influence on a student's decision to pursue a career/interest in science. 3 I must actively create/promote a learning environment that is...	4 5My role as teacher is to present scientific knowledge during class. 4 Female and male scientists experience the workplace in the same way. (added "?") 4 Females have not been encouraged enough in middle/high school to excel in science.(don't know ?) 4 Science and society influence each other; science shapes and reflects the current cultural and political context. 4 Science is competitive. 4 Science is Euro-centric. 4 Science is intimidating to some. 4 Scientists are open-minded, logical, unbiased, and objective in their work. 4 Students who have not excelled in high school science should probably not consider a career in science.	5 4My beliefs about the nature of science influence how I teach. 5 I am comfortable with the notion of professor/teacher acting as "coach" or "guide" during class. 5 Most scientists are white males. 5 My role as teacher is to invite students to participate in the scientific community. 5 Science is beneficial. 5 Science is creative. 5 Science teachers should make learning relevant and meaningful to all students. 5 Women and minority scientists have made important contributions to science.

Table 8 continued next page

Table 8 continued

Strongly Disagrees (1)	Generally Disagree (2)	Neutral or Don't Know (3)	Generally Agree (4)	Strongly Agree (5)
	2 Succeeding in science is more difficult for females for sociocultural reasons.	3 It is more important for students to spend time learning scientific facts and concepts than to spend time "behaving as scientists". 3 My role as teacher is to instill a critical perspective in students about the enterprise of science in regards to who creates the knowledge and who benefits from it. (added "?") 3 Science is exclusive. 3 Scientists are unique and special. (Everyone is unique and special) 3 The experiences, interests, and values of the scientist influence scientific research. (didn't answer)		

Table 9: Biochemistry Department Student Enrollment

Internal Enrollment Table												
Undergraduate And Graduate Student Majors By Ethnicity and Sex Fall Semester 2000 College of Natural Sciences and Mathematics												
Department		Undergraduate				Graduate						
		Asian, Pacific Islander	Black, Non-Hispanic	Hispanic	White, Non-Hispanic	Non-Resident Alien	Non-Reporting	Asian, Pacific Islander	Hispanic	White, Non-Hispanic	Non-Resident Alien	Non-Reporting
BIOCHMEMISTRY	Female	17	5	0	36	4	6	0	0	3	1	1
	Male	12	10	2	52	0	14	1	0	3		0

Note 1: Race/Ethnicity is based upon students' voluntary self report
Note 2: Students are counted according to the location of their primary major.
(Source: University Office of Institutional Research)

Table 10: Phase I Faculty Questionnaire Data: Mary

Strongly Disagrees (1)	Generally Disagree (2)	Neutral or Don't Know (3)	Generally Agree (4)	Strongly Agree (5)
1Students who have not excelled in high school science should probably not consider a career in science. 1 Traditional teaching methods and course structure allow all students to succeed equally in science. 1 1 Students learn scientific knowledge. 1 (Students learn science many different ways.) 1 Stereotypes... 1 (Nope, everyone has to start somewhere near the beginning when they learn something new, regardless of anything else.) 1 Some students cannot do science. 1 (Some students don't want to learn science) 1 Scientific knowledge develops as a result of socially constructed ideals of worthiness. 1	2 Females and males drop majors in science, mathematics, engineering, and technology programs primarily because of poor teaching. 2 (Many factors are involved including poor teaching, but also poor learning/study habits on part of the students, the expectation that learning "should be" easy when it is actually hard work, and lack of resources for educational materials that enhance learning.) 2 Females and males are enrolled in science, mathematics, engineering, and technology degree programs in roughly equal numbers. 2 (But I also know that women are no longer considered by NSF to be an under represented minority in fields like molecular biology!)	3 Scientists investigate phenomena following an established philosophy, purpose, and methodology that is grounded in the beliefs of early European scientific societies. 3 3 Science is exclusive. (Yes and no. Doing cutting edge scientific research is "exclusive" to those "qualified" by sufficient education, training and experience to be able to raise the money to do the research. On the other hand science is inclusive as it arguably determines every thought and move, and orchestrates all life!) 3 It is more important for certain students to spend time learning scientific facts and concepts than to spend time "behaving as scientists". I don't understand this question.	4 Succeeding in science is more difficult for females for sociocultural reasons. 4 (I am not exactly sure what "sociocultural" really means but in the end it is the time consuming and financially draining experience of having children that interferes with women advancing in science. Women are competing daily with men who not only have children but best of all they have wives. Usually.) (When is the "right" time to start a family? College? Grad school? Postdoc? During your first job? Before or after your tenure decision? When?) 4 Science and society ... (Statement is too general. Science and society definitely influence each other, but science deals with facts while culture and politics often deal not with facts but with perceptions of the truth.)	5 Women and minority scientists have made important contributions to science. 5 (I always tell people to remember Roslind Franklin when you think of Watson and Crick) 5 Scientists are unique and special. 5 (Yes, and misunderstood and unappreciated as well!) 5 Scientists are open-minded, logical, unbiased, and objective in their work. 5 (GOOD scientists strive to do this...) 5 Scientific knowledge is constrained by funding, politics, and researcher interest. 5 5 Science teachers should make learning relevant and meaningful to all students. 5 5 Science is intimidating creative competitive beneficial.

Table 10 continued on next page

Table 10 continued

Strongly Disagrees (1)	Generally Disagree (2)	Neutral or Don't Know (3)	Generally Agree (4)	Strongly Agree (5)
Often quite the opposite in fact, scientific knowledge can be at odds with "social ideals") 1 Science is Euro-centric. 1 (I think Euro-centric means focused on or based in Europe???) 1 Males have more scientific abilities than females. 1 1 Female and male scientists experience the workplace in the same way. 1 1 Female and male scientists enjoy equal pay, tenure status, and job placement (in industry/government/education). 1 (No way.)	3 I don't know because I have not yet taught gen ed students, but I suspect that most students are primarily interested in passing the course…!!!)		4 Non-western scientific practices may be valid constructions of science. 4 (What do you mean by "valid constructions of science"? My answer is that some "non-western" scientific practices such as medicinal uses of herbs etc or acupuncture are valid and can be interpreted using scientific facts. Many people forget that most of our western drugs began as "natural" substances such as plants, which have been processed to put into pill form). 4 As teacher, I am the greatest influence on a student's decision to pursue a career/interest in science. 4 (A major influence but not necessarily the greatest influence) 5 Females have not been encouraged enough in middle/high school to excel in science. 5 5 Anyone can become a scientist. 5 (I think it is true that most young children are scientists)	5 My role as teacher is to present scientific knowledge during class. 5 Yes, ONE of my roles is to do this. 5 My role as teacher is to invite students to participate in the scientific community. 5 5 My role as teacher is to instill a critical perspective in students about the enterprise of science in regards to who creates the knowledge and who benefits from it. 5 5 My beliefs about the nature of science influence how I teach. 5 5 Most scientists are white males. 5 5 I must actively create/promote a learning environment that is supportive of male/female/ethnic/minority students equally. 5 5 I am comfortable with the notion of professor/teacher acting as "coach" or "guide" during class. 5 (Yes, part of the time!) 5 Almost anyone can understand science if she/he studies enough.

Table 11: Faculty Participants, Course, Course Support, & Student Enrollment

Participant/ Discipline	Years on Faculty	Course Taught	Years Course Taught.	Years Course Taught By Professor	Students in Course	Course Support Personnel
Mary Gibson Biochemistry full professor	20	Introductory Genetics	0	0	20 students 90% nonscience majors	6
Jim Willis Geology assistant professor	3	Introduction to Earth's Oceans	30	0	600+ students 90% nonscience majors	2

Table 12: Faculty Participants' Course Expectations & Concerns

Faculty Participant	Expectations of Course Content	Expectations of Teaching Content	Expectations of Student Activity in Course	**Feelings & Concerns**
Mary Gibson	Intrinsically motivating and integral to everyday life	DISTILL KNOWLEDGE TO MAKE IT ACCESSIBLE TO STUDENT ABILITY LEVEL	♦ Completing homework reading ♦ Attending class, taking notes, asking questions in class, studying notes, completing in-class assignments/quizzes, exams ♦ Requesting extra help via office hours, email, phone calls, attending help sessions	♦ Excited to introduce students to subject. ♦ Adapting content and lecture presentations to students' ability and interest levels. ♦ Assessing student understanding and interest. ♦ Student passivity. ♦ Coordinating implementation effort of new course. ♦ Course development taking up too much time.
James Willis	Intrinsically motivating and integral to everyday life	Distill knowledge to make it accessible to student ability level	♦ Completing homework reading ♦ Attending class, taking notes, asking questions in class, studying notes, completing in-class assignments/quizzes, exams ♦ Requesting extra help via office hours, email, phone calls, attending help sessions	♦ Excited to introduce students to subject. ♦ Adapting content and lecture presentations to students' ability and interest levels. ♦ Assessing student understanding and interest. ♦ Student talking. ♦ Personalizing course to instructor's interests/goals. ♦ Day-to-day personal responsibility of preparing lectures, lecturing, grading, and working with students. ♦ Teaching and personalizing course taking up too much time.

Table 13: Phase I Student Questionnaire Summaries (Introduction to Earth's Oceans Course)

Questionnaire Statement	Student Responses (n=235)
I expect that what I learn in this course can be applied to my everyday life.	~ 30%
I expect that what I learn in this course can be applied to my future career.	40% females 48% males
Everyone should learn about the oceans and how they affect our existence	~ 50%
Understanding how scientists think and solve problems is useful for me to learn.	~65%
I should understand how scientific theories about the oceans developed.	~25%
Climate change is an important issue.	60% females 69% males
The oceans impact my life.	~60%
I am interested in learning about the oceans.	75% females 65% of the males
My past science class experiences had been positive.	71%
Thinking scientifically will be useful in my future.	54% females 71% males
I am good in math.	47% females 68% males
Males and females can do equally well in science.	87%
I had considered majoring in science at college.	36%
If I chose to major in science that the professors would support and assist them.	70%
Scientific findings benefit all people everywhere.	90%

Table 14: Introduction to Earth's Oceans Course Student Interview Participants

Student	Ethnicity	Academic Status	Major
Alex	Caucasian/	Junior	German
Carly	Caucasian/	Sophomore	School of Management
Cindy	Caucasian/	Freshman	Undeclared (Sociology and Elementary Education?)
Ellen	Caucasian	Freshman	Pre-Journalism
Eric	Asian/Caucasian	Junior	Exercise Science
Gwen	African-American/Caucasian	Freshman	Psychology
Kate	Caucasian/	Freshman	History (and middle school education?)
Lisa	Caucasian/	Sophomore	English/Education
Melissa	Caucasian	Freshman	Undeclared
Pam	Korean American	Freshman	Communications
Roger	African-American	Freshman	Undeclared
Sierra	Caucasian	Freshman	Undeclared
Sophie	Caucasian	Senior	Sociology
Luon	Korean	Junior	Hotel Restaurant
Zac	Caucasian/	Freshman	English/Education

Table 15: Phase I Student Questionnaire Summaries (Introductory Genetics Course)

Questionnaire Statement	Student Responses (n= 18)
I expect that what I learn in this course can be applied to my everyday life.	65%
I expect that what I learn in this course can be applied to my future career.	58%
I think everyone should learn about DNA.	84%
Understanding how scientists think and solve problems is useful for me to learn.	73%
It is useful for me to understand the science of how DNA works.	84%
In general, I am interested in science topics.	90%
My past experiences in science classes have been positive.	78%
To do well in science you have to be good at math.	52%
I am good at math.	58%
Males and females can do equally well in science.	94%
I have considered majoring in science at college.	64%
If I chose to major in science today I believe the professors would support and assist me.	53%
Scientific findings benefit all people everywhere.	79%

Table 16: Introductory Genetics Student Interview Participants

Student	Ethnicity	Academic Status	Major
Caroline	Caucasian	Freshman	Business
Annette	Caucasian	Freshman	Microbiology
Lydia	Caucasian	Freshman	Psychology
JANET	Caucasian	Freshman	Sociology
Winston	Asian	Sophomore	Computer Science
Amanda	Caucasian	Junior	English
Jake	Caucasian	Junior	Microbiology
Heidi	Caucasian	Senior	History
Tom	Caucasian	Senior	Psychology

Table 17: Action Research Questions and Actions: Jim

AR Question	Evidence for Question	Methods for finding answers	Findings	Evidence for Findings	Action or No Action Taken
1.) How do make it [a course] interest females? How do you get more females to want to be involved? (phase I interview notes, 1/22/02)	We briefly discussed the faculty survey and he expressed interest in issue	Discussions with me, student interviews.	Findings: keep group activities, keep good visuals, strive for relevancy	Literature base, my knowledge base. Student comments	Focus on clear content presentation w/o explicit consideration of female learning styles/interest/needs. A few times in lecture says, "why are we learning this? Etc." Course runs as usual, with more time spent lecturing actually.
2.) How can I keep students from talking during lectures? (phase I interview, 1/22/02) Am I losing respect because of the talking and is it bothering other students? (3/6 conversation)	He mentioned that he would use a contract that other professors had devised to make explicit his expectation for quiet during lectures.	Asks students to complete a 1+1 course comment sheet at a review session. Discussions with me.	Findings: it is bothering other students, etc.	Student quotes, my notes from class on day that I felt the students didn't know he was trying to start.	Tells students they will get out early if he doesn't have to stop. Approaches students after class who were talking (5/7 incident), being disruptive, arriving late. Daily reminders on announcements to pay attention. Stops lecturing when students are talking. Tells students they are missing notes and won't have to study for exam. Puts students' quotes up on overhead about talking to show it does bother other students.

Table 17 continued on next page

Table 17 continued

AR Question	Evidence for Question	Methods for finding answers	Findings	Evidence for Findings	Action or No Action Taken
3.) Personal effort to find time to redesign and design Powerpoint lectures and make them effective tools for learning. [How I?]	Talks about not being able to use other professors' slides, he wants to focus on other information, at his own pace. (2/7 inf. Conversation, 3/26)	Sets up week so that Tues/Thurs are the only days to work on course, time to prepare lectures before 11:15 class. He does what he can in that time.	Organizational and time management idea is better than working all the time on course. Still swamped and out of time.	Conversation, interview comments (too much info, too fast)	Survival mode – continues to redo lectures. He slows down during lecture, creates slides with less information (ex, took out Sea Ice Fm on 3/?) on them, gives students lots of time to copy down, reviews last lecture notes.
4.) How do I make use of the workbook?	He feels constrained by workbook , students bought it, he should use it, he's not in sync with it – he likes the idea of group work but the activities don't mesh for him (3/26)	Interviews, conversations		Classroom observations, comments	Does not use workbook each week, completes about 4 exercises between exams. Assigns a few for homework and not in class. Uses blank sheet in workbook for a review activity about global wind patterns (3/26).
5.) Are the exams too hard?	Comments after first exam	Student comments to him, grades. Interview notes from students.	Exams too tricky and difficult. Need study guides. Group exam idea, for most students, is a good thing, they learn while they take exam.	quotes	Continues with group exams. Puts study guides on webpage. Makes exams less tricky, easier. Grades improve.

Table 18: Action Research Questions & Actions: Mary

AR Question	Evidence for Question	Methods for Answers / Findings	Evidence for Findings	Action Taken or No Action Taken
How do you teach in a way that makes the topic of DNA important to students? How do you show/help them make connections to the science and their own lives? Can I assess understanding by listening to their language when they speak about the topics? Phase I: Mary Am I doing too much talking? Can the students be more active?	Introductory and Phase I interview: Mary talks about course development effort and need for relevancy and connecting to students. She wants to find the "basic things" students need to know to understand DNA, how to make language accessible to students. Describes how in the beginning they will be hesitant to talk – will get more comfortable over time. Phase I: M: Well, in the beginning it seems to be that they are going to go from being in their own little - right now they are uncomfortable with the topic, with the idea, they are uncomfortable with this whole thing. And the first shift is that they become more comfortable asking questions and talking about things that – where previously the vocabulary didn't exist –	Methods: Student interviews, 9 classroom observations, email correspondences with students, informal conversations with instructors, document analysis Findings: Mary creates comfortable welcoming atmosphere for students. Enthusiastic, informal, interesting. Practically the same 25% of students ask/answer	Mary very welcoming to students with her language, gestures, expressions - noticeable as new students joined class over first 2 weeks. She introduced everyone and let students know that they could contact anyone with questions – gave out lots of information on herself and team. Uses humor, brings in personal stories. Always soliciting students for questions – asks 3-5 times per lecture. Asking questions each class (varies, 3-10). Wait time could be better. Students see diagrams/text/computer visuals of DNA and other molecules/short movies of DNA processes/political cartoons/media slides to show the popularization of topic/Historical images of people/situation/scenes. Presentations are colorful, varied . Liza has similar open demeanor – students not afraid to ask questions. Liza asked student his name after he asked a question.	After 3/7: Powerpoint presentations made accessible online. OWLs made more straightforward – not as tricky. In class – talks about what students are saying about readings, that they are more complicated than earlier ones, she "slows down" and reviews some of the reading information on genes 3/12 – M asks students to write down questions that they are having, continuing to implore them to ask.

Table 18 continued on next page

Table 18 continued

AR Question	Evidence for Question	Methods for Answers / Findings	Evidence for Findings	Action Taken or No Action Taken
Is there too much material? How do students feel about the course? How can I allow the others on the MyDNA team to act on/learn about the things they need to? Phase I: Liza Is the computer usage working? Are students accessing slides on web? Are they useful? Are OWL quizzes useful?	T: So are you hoping to see them asking more questions in 2 weeks? You are hoping to See a progression like this? M: But I'm not sure Phase I meeting notes: Wanted to do more with the NOVA survey in class but ran out of time. Students can let her know if there are problems – a few students ask questions during class – hard to know how they feel about the course. Mary wants to get ahead by a lecture – to give Liza time to do other things, thinks OWL is useful – a way of keeping students. up with material. Liza – Are students accessing Powerpoint slides on the web? Is it helping their learning? It feels like to L she is just giving them the notes, is that okay? Are OWLs useful?	questions during class (tend to be science students and upperclassmen).	Lots of talk about scientific language – that it doesn't need to be hard (2/5, 2/14 observation– the content *is* understandable. There is an awareness of language as an issue for students - with the focus on supporting their learning and comfort level with the science.	3/28 M changed PCR on syllabus to meet informational needs of students' projects. 3/28 slide: creates slide called Questions for MyDNA, leads students through a review on how to clone. [a unique situation, a kind of guided lecture to promote ideas and questions – most students didn't respond, they waited, the usual males spoke, is this an explicit attempt to get more students to talk - ?] 4/23: Quiz – students write definition of words out in a paragraph.

Table 19: Departmental Contexts: Mary & Jim

Professor	Dr Mary Gibson	Dr. Jim Willis
Years at University	20	3
Status	Full Professor	Assistant Professor
Department	Biochemistry College of Arts & Sciences	Geology College of Arts & Sciences
Dean	White Male (note: prior female dean from biochemistry department)	White Male
Faculty: Females/Males	~50% female ~50% male	20% female 80% male
Faculty: Ethnicity	< 1% Persons of color	<1% Persons of color
Undergraduates	168 ~33% female ~66% male > 66% White, Non-Hispanic	75 ~50% female ~50% male > 99% White, Non-Hispanic
Graduate Students	9 (check data with dept.)	52 ~33% female ~66% male >99% White, Non-Hispanic
Identity in Science	Prepare students for professional sector in medicine & scientific research	Prepare students for industry (petroleum, environmental, mining), scientific research, & teaching

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